THE ONTONAGON BOULDER.
From a drawing made in 1819.

THE COPPER MINES
OF
LAKE SUPERIOR

BY

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THIS LITTLE BOOK

IS

DEDICATED

TO

JOHN STANTON

IN CORDIAL APPRECIATION OF LIFE-LONG SERVICES,
WHICH HAVE BENEFITED NOT ONLY THE COPPER MINES OF THE UPPER PENINSULA, BUT THE BEST INTERESTS OF A WORLD-WIDE INDUSTRY.

CONTENTS.

PREFACE

ANY good American, desirous of impressing an intelligent visitor from another country, say, for example, Macaulay's New Zealander, with the permanent and profitable character of the mining industry of the United States, would be wise in choosing the copper country by the Great Lakes in preference to any other of our splendid mineral regions. Sixty years of productiveness represent history in our unresting industrial growth; an annual yield of 200,000,000 pounds of refined copper is in itself impressive, for it means 15 per cent of the total output of the world; mines one mile in vertical depth appeal to the imagination; a single stamp that crushes 700 tons of ore *per diem* has a thunderous way of proclaiming its importance; well-ordered communities aggregating about 80,000 self-respecting people indicate favorable conditions of living; and, when the visitor is weary of the immensity of the operations carried out by man on the Keweenaw Peninsula, he can turn with deep restfulness to the splendor of earth and sky, to the beauty of forest and wave, to the long promontories dividing the surface of Lake Superior, and the blue line of the Huron mountains.

As the traveler journeys from Buffalo to Houghton, and thence to Duluth, on a steamer itself of dimensions that challenge many Atlantic liners, he is stimulated by a swiftly moving panorama of shores on which every kind of industrial development is proceeding; he will encounter the vast freightage which bears the produce of the northwestern wheatfields, the iron ores that are the material foundation of modern civilization, the lumber from the Michigan forests, and the copper on its way to the refineries of New Jersey; this traffic being met by vessels heavily laden

with coal, merchandise, machinery and the immense supplies consumed in the exploitation of natural resources of great diversity. He will be on an internal waterway which is 2,100 miles long from Duluth to the mouth of the St. Lawrence, a continental line of communication the traffic of which, as measured at the locks of the Sault Ste. Marie, is more than double that of the Suez canal. And it is impressive, not as measured by tonnage alone, but because instead of the sand marshes of Suez, the barren mountains of Sinai, and the blistering deserts of the Libyan coast, this great commercial artery of North America separates, and unites, two English-speaking nations whose multitudinous energies are expressed in an uninterrupted succession of mills and factories, docks and railroads, and a continuous line of throbbing steamers that bear the commerce of a continent down the long-linked series of lakes, canals and rivers to the marts of the world.

It is this mining region which I have endeavored to describe, by the aid of observations and information secured during three weeks in the summer of 1904. For much of my material I am indebted to the courtesy of mine managers and engineers, whose names are mentioned, with grateful acknowledgment, in the pages that follow. During the whole of my stay at Houghton I received the help, and frequently the stimulating companionship, of Mr. F. W. McNair, president of the Michigan College of Mines, and of Mr. L. S. Austin, professor of metallurgy in that most efficient technical institution. To these two friends I am under particular obligations.

One matter, to which I regret to refer, requires mention in this account of the copper mines of Lake Superior; for, unpretentious as my story is, I desire it to be an honest portrayal of mining affairs in the Upper Peninsula during the year 1904. Therefore, this explanation.

Those who read these pages will be surprised—and disappointed—to find only scant reference to the two mines

which have done most to give the region a world-wide celebrity; I refer to the Calumet & Hecla and Tamarack. As a matter of fact, beyond the impressiveness of size and the romance of a great production, the engineer is likely to find the younger mines as rich in suggestion and interest, as the two great properties referred to. Nevertheless, the fact that they follow a conglomerate lode, while the other mines —all, save the Franklin Junior—are founded upon beds of amygdaloid, gives them a peculiar geologic interest, heightened by the analogy with the 'banket' of the Rand. Furthermore, their workings have reached the depth of 5,000 ft., and they must therefore afford interesting data concerning the obstacles to deep mining. These two matters of interest I was unable to study and describe. Since the object of the investigation made by me was simply to afford data which might prove useful to professional men in other districts and in other countries, and at the same time elicit corresponding information for the use of my friends in Michigan, I regret the refusal of admittance to these two mines. As a mine manager of experience, I understand that the indiscriminate admission underground of laymen and tourists is a source of danger and entails a consumption of time on the part of the staff such as the public does not appreciate; but the closing of mines to properly accredited mining men is a different matter. Do the directors of these two companies appreciate that 99 per cent of the knowledge upon which their highly successful operations are based, is knowledge which was given gratuitously by other men working other mines? Of the improvements introduced at the Calumet & Hecla and the Tamarack during, say, the last ten years, how much was a free gift coming from the experience of mining engineers not in the employ of these companies, but engaged elsewhere? Mine managers do not get knowledge by spontaneous cerebration. However, in making a protest against a practice which goes against all the instincts of a generous profession, I do not criticise the

gentlemen who are in charge of these two properties; on the contrary, I acknowledge personal courtesies which it will always be pleasant to remember, and I appreciate cordially how humiliating it must be to them to be unable to afford the facilities which will invariably be afforded to them when they visit their professional friends in other parts of the world.

T. A. RICKARD.

New York, December 15, 1904.

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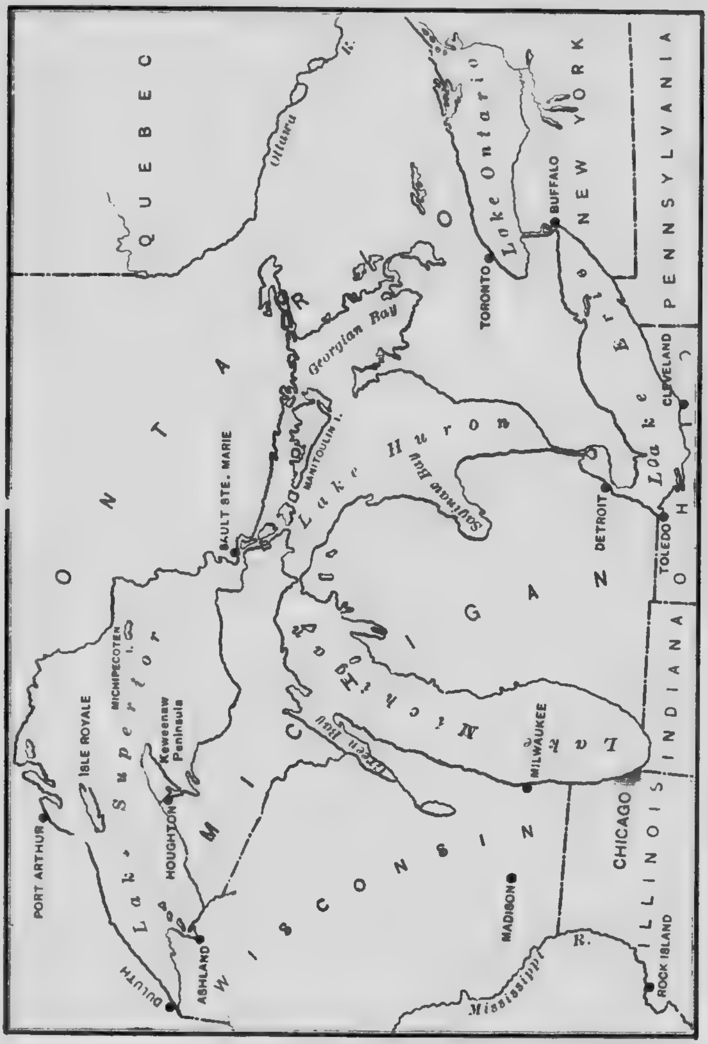
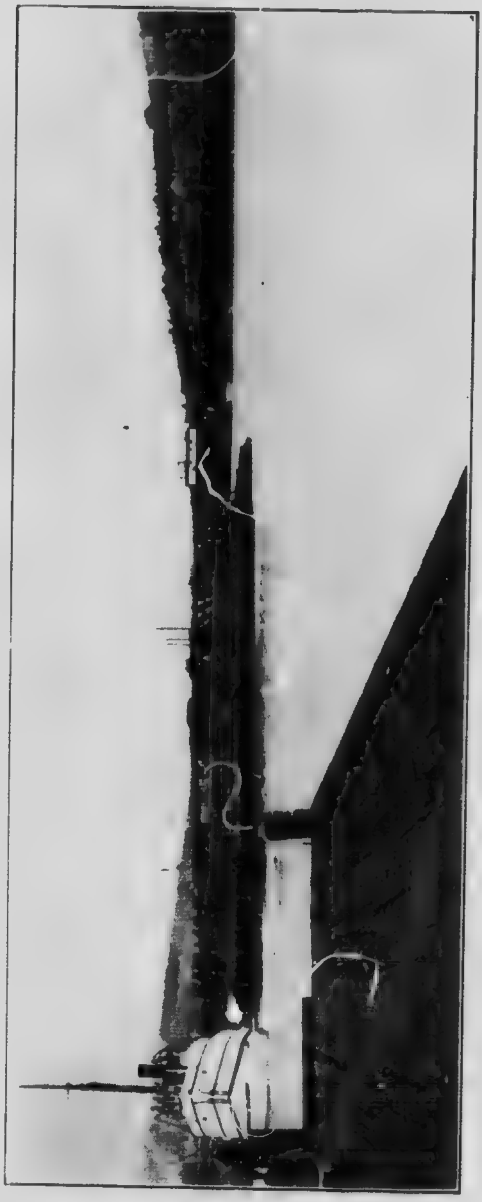
I.—Introductory.

IF the reader will take a map of North America and look at the Great Lakes which separate the United States from Canada, he will see a solitary tongue of land projecting from the south shore into the center of Lake Superior. That is the Keweenaw peninsula, a part of the State of Michigan, and the copper-mining region which it is my purpose to describe. On a map of the United States it will appear that Houghton is an inland town in the south-central portion of the peninsula, and there will be but little hint of the fact that it is situated on a waterway which renders the northern half of the region, not a peninsula, but an *insula*. The Portage lake and river, with the canal that forms the western outlet to Lake Superior, are, in fact, only links in that long line of water communication which reaches from Duluth, through the Great Lakes, to the mouth of the St. Lawrence, a total distance of 2,100 miles.

The wheatfields of Manitoba, the iron ores of Minnesota, Wisconsin and Michigan, the copper of the Michigan mines and the lumber of the forests, all reach an outlet along this inland waterway, so that it is not surprising to find that the locks at the Sault Ste. Marie register a tonnage which, for the eight months of navigation, is more than double that which passes through the Suez canal during an entire year. In 1903 the traffic passing the Sault Ste. Marie amounted to



MAP OF THE GREAT LAKES.



WHARF AND BRIDGE AT HOUGHTON.

34,674,437 tons, on which freight charges amounting to $26,727,735 were paid. Mineral products were as follows: Iron ore, 21,654,898 tons; coal, 6,937,633 tons; copper, 112.877 tons, and salt, 454,822 barrels.

From New York, the traveler goes by train, 440 miles in nine hours, to Buffalo, and there takes steamer. The *North West*, on which I traveled, is 386 ft. long, 44 ft. beam, has a rating of 5,000 tons, with 8,000 h.p., and draws 17 ft. of water. It is not many years since such a vessel would have been considered a large craft, even on the Atlantic. Comparison may be made with the White Star steamers on the Pacific, which are 420 to 441 ft. long, 42 to 44 ft. wide, with a rating of 4,205 to 4,676 tons.

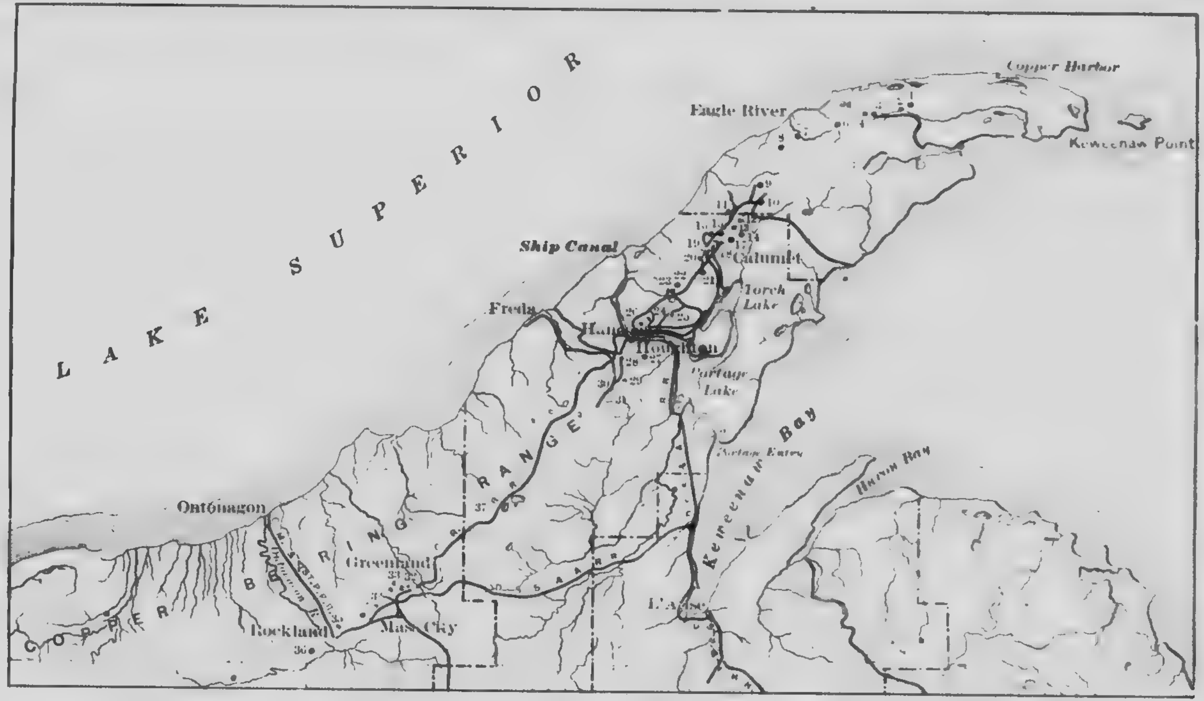
From Buffalo to Houghton the distance is 811 miles, which required a voyage of three nights and two days—days of unclouded beauty, spent on quiet waters and diversified by the swiftly moving panorama of a country undergoing a variety of industrial development. On a sunny morning in August the *North West* steamed up the arm of Portage lake, here only half a mile wide, and drew up at the wharf just below the drawbridge uniting the towns of Houghton and Hancock, which lie at the foot of two facing hillslopes of gentle demeanor. Beyond the drawbridge the shimmering waters of Portage Arm disappeared around a wooded bend. The scene breathed a quiet and orderly spirit; there was none of the uncouth ruggedness or the squalid unrest which one associates with mining activity; the air contrasted refreshingly with the sweltering turmoil of New York City; and, not till I recognized the shafthouses on Quincy hill, the smoke of the smelters at Hancock, the buzz of a lively saw-mill, and the cluster of red buildings marking the College of Mines, did I realize that I had indeed reached the port of entry to a mining region famous throughout the four corners of the globe.

The larger number of productive copper mines are in the northern part of the peninsula, in a series extending from

HANCOCK AND QUINCY HILL

Hancock to Calumet, and a little beyond, making 15 miles altogether; another important group of growing mines is found south of Houghton, to a distance of 8 miles. Beyond this continuous mining belt, there is the outlying district of Eagle River along the northern edge of the peninsula, and to the south there is the Ontonagon country. The accompanying map will make this clear.

The present population of this mining district is about 78,000, of whom 38,000 are distributed over the town of Calumet and its adjoining suburbs of Laurium, Red Jacket, Blue Jacket, Hubbell and Limerick. Besides the towns mentioned, there are smaller settlements, mainly of workmen's houses, near the Centennial, Wolverine, Mohawk and other individual mines. Across Portage lake, on the South Range, there is a village of about 3,000 people at Atlantic, with smaller communities at Huron, Trimountain and Painesdale. At Hancock there are 7,000 and at Houghton only 4,000 inhabitants. Hancock and Houghton are divided by the arm of Portage lake, but united by a drawbridge. Both are pretty, clean-looking communities, the better residences being on College avenue, overlooking the water and dominated by several fine buildings, among them the East Houghton school and the imposing cluster which marks the College of Mines. An excellent electric car service unites the twin towns with Calumet, 12 miles distant. This large settlement is more evidently a mining community, because the big shaft-houses of the Tamarack and Calumet & Hecla mines soar above the streets and dominate the surrounding houses in a lordly way. Calumet is a community of many nationalities; among the workmen employed by the Calumet & Hecla mine, 38 nations are represented. Hence the multiplicity of religions and the corresponding diversity of 'thirst-parlors'; one might say that there is a conglomeration of churches and an amygdaloid of saloons. When walking the streets, one overhears many strange languages, from the homely Cornish dialect



THE KEWEENAW PENINSULA. Each rectangle is a township, 6 miles square.

KEY TO MINES.

1. Aetna	9. Mohawk.	17. South Kearsarge	25. Arcadian	33. Adventure
2. Empire	10. Ahmeek	18. Calumet & Hecla	26. Quincy	34. Mass
3. Delaware	11. Allouez	19. Tamarack	27. Isle Royale	35. Michigan
4. Amygdaloid	12. North Kearsarge	20. Osceola	28. Atlantic	36. Victoria
5. Copper Falls	13. Wolverine	21. Tecumseh	29. Baltic	37. Winona
6. Central	14. Mayflower	22. Rhode Island	30. Trimountain	
7. Phoenix	15. Centennial	23. Franklin, Jr.	31. Champion	
8. Cliff	16. Tamarack, Jr.	24. Franklin	32. Belt.	

to the foreign accents of Finland. There are signs and names variously intelligible to the traveler, according to the prevailing humidity, from *Paiva Lehti* to *Soumalainen Saloonki!* Notwithstanding the extraordinary mixture of races, disorderly scenes are rare and the police are conspicuously few in number, one reason probably being the insular position of the district, exit from which is either over the Houghton-Hancock bridge or by boat on the surrounding waters.

While underground at the Baltic mine, on the South Range, I saw a code of signals at the shaft-station, the explanations being given in English, Finnish and Italian, respectively. At the Wolverine the changing house is arranged for various nationalities, the English taking one end of a changing room and Italians the other; in a second room the Austrians have one half, while the other is set aside for Finns.

Of the numerous nationalities the Cornish are eminently the best miners, and next to them come the Finns. In early days the Irish were more numerous than at present, and they used to have frequent 'scraps' with the Cousin Jacks, as the men from Cornwall are called. When the Swedes and Finns began to come in, the Irish and Cornish tended to draw together. The Finns are separated by a distinct cleavage into "temperance Finns" and the "others"; the latter are apt to be rampagious when under the influence. The former make excellent citizens; they come from a rigorous climate and an ungrateful soil, and they are now cultivating the forest clearing with such marked success as to develop a profitable agriculture in this northern country. They do not stick to mining long; from trammers they graduate quickly to miners, and then, after about ten years of continuous work, according to the amount of their savings, they either take up a tract and clear the forest from it, or buy a farm already made.

The miners are mainly Cornishmen and Finns; the tram-

mers are Finns, Italians and Austrians; the timber gang is apt to have a Cornishman as chief, with Austrians for helpers. The latter are really Croatians, for the most part; they are quiet, hard working and peaceable. The Italians are often divided among themselves by feuds identified with the localities of their origin (those who know Italy, are aware of the antipathy between the people of separate provinces); the consequence is that at the present time most of the Italians in this district come from Piedmont; and, when any miners arrive from other parts of Italy, they are treated as 'outsiders,' getting so little help from their compatriots that they usually depart to more hospitable surroundings. The Finns are ambitious, stubborn and thrifty; they are quite separate from the Norwegians and Swedes; they work hard and are generally educated to the point of a little reading and writing, which cannot be said of all the other foreigners. But the Cornishmen hold their own, beyond question; they are the most capable miners, having a great eye for ore, and an hereditary instinct for "reading the signs" underground. At the Atlantic mine, where a low-grade ore has caused the contract system to act as a process of natural selection, the Cousin Jacks have proved the most fit to survive amid keen competition, the result of which is expressed by the fact that most of the miners are Cornish, with a few Finns, the latter often making up in muscle and persistence for lack of inherited instinct. The Cornish hate shoveling, and prefer to do the actual breaking of ground, and for this reason they are better miners than laborers. Many good stories are told of them: One day a superintendent, making his rounds, called up to a couple of Cornishmen who had a hard contract. He asked how things were going. "How is it, boys?" "Mighty 'ard, Cap'n; she's pretty tough." "Well, boys, brace up; what you want is pride and perseverance to help you." He went on. Behind him he heard the two miners: "Say, Bill, who be they, Pride and Perseverance?" "I

doan't know, Tom—guess they be the two Finns in the next stope."

Rarely is the laboring man better off than in this district. Wages average from \$2.30 to \$2.50 per shift for miners, and from \$2 to \$2.25 for trammers, contractors doing about 25 per cent better. Board is from \$16 to \$18 per month; the rent of a four-room house is from \$4 to \$6 per month. The companies build substantial dwellings, usually with stone foundations, arranged in orderly rows, whose neatness and regularity have not much of the picturesque, but bespeak far healthier conditions than that mingling of the squalid and romantic which characterizes other mining camps. At Painesdale and at Calumet, two presidents of well-known mining companies have given library buildings for the use of workmen; and at Houghton, the College of Mines has a reference library of worthy proportions. The necessities of life are not high; the climate is healthy; good schools are plentiful; hospitals are easily available; and, on the whole, it is obvious that the miner in this region is better off than the higher paid men who live amid the desolations of Arizona and Nevada, or among the even more brutalizing environments of such places as Butte City and Broken Hill.

The copper mines owe to Lake Superior more than their geographical habitat. Their milling practice has been modified profoundly by the unlimited supply of fresh water available for the mills, which, requiring as they do about 3,500,000 gal. per stamp per day, would soon exhaust an ordinary inland stream; the splendid forests that clothe the surrounding country have furnished the enormous supply of timber required for the support of excavations underground; and the tax upon even the resplendent woodlands of Michigan can be appreciated when it is stated that the Tamarack mine alone engulfs half a million feet, board measure, of timber monthly. Beside wood and water, the mines have been furnished a magnificent highway of transport. An excellent bituminous coal comes from

Pittsburg, 150 miles by land to Cleveland, and thence by water 735 miles, at a cost of $2.66 per ton; of which only 30 to 40 cents is the steamer freight, and 8 cents per ton the cost of unloading.

The loading and unloading is done on a big scale; at Cleveland, by the shore of Lake Erie, I saw cars holding 50 tons of coal apiece emptied bodily, as if they were small buckets, into a vessel, at the rate of 1,000 tons per hour; and, while I was at Houghton, the *Martin Mullen*, a lake steamer, brought a load of 7,200 tons of coal, and unloaded

the whole of it at the dock of the Copper Range Railroad within two days. At other lake ports, possessing better facilities, the unloading is done at the rate of 10,000 tons in 4½ hours. These facts impressed me as I remembered the coaling of a mail steamer at Port Said; a long string of coolies walking a gang plank, carrying coal in little willow baskets on their heads, entering one hatchway, discharging their burden and trotting down a neighboring gangway, singing monotonously all the time, with the result that the passengers were given 8 to 10 hours of sooty unpleasantness while a few hundred tons of coal were taken aboard.

II.—Geology.

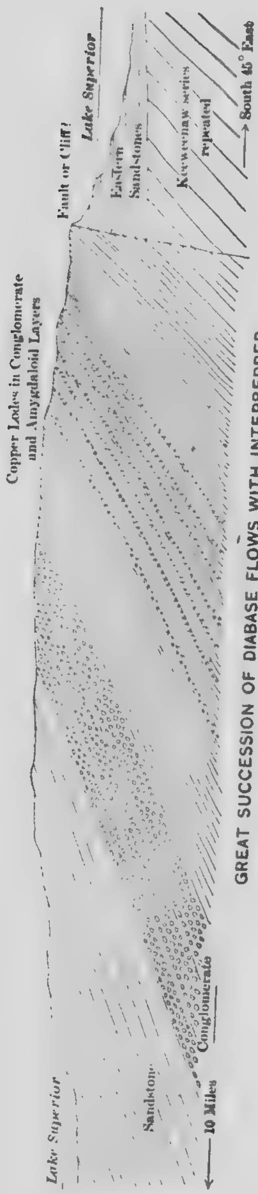
The Keweenaw peninsula, as measured along its line of departure from the mainland, is about 40 miles across, east to west, and extends northeastward into Lake Superior for about 70 miles. It is dominated by a central plateau rising to 600 ft. above the lake level, the general structure being that of a broad backbone of uptilted beds, largely of volcanic origin, flanked on both sides by sandstones, whose eroded edges slope under glacial drift to the shore. At Portage lake, where the peninsula is cut in two, the width is less than twenty miles.

The backbone of this landspur is a wide belt of rocks known as the Keweenaw series, comprising a succession of lavas of extrusive origin with interbedded layers of sandstone and conglomerate. While the igneous members of the series are composed of rocks differing in chemical and physical constitution, they can be described briefly as varieties of diabase,[1] considerably altered, with which are associated rocks of greater acidity, from porphyrites to quartz porphyries. The conglomerates are composed of rounded fragments of these rocks, the more acid predominating

The Keweenaw series has a thickness of 25,000 to 30,000 ft.,[2] and in adjacent regions the thickness is even greater.

[1] 'Diabase' is the term employed by Irving, 'melaphyr' that used by Pumpelly, and 'melaphyre' by the Michigan Geological Survey. The State Survey, of late years, has tried to reserve the term 'diabase' for intrusive rocks, although some of the Keweenaw beds undoubtedly have the structure of diabase. (See Vol. VI, Pt. I, pp. 169 and 220.) 'Melaphyre' as a rock name is now almost obsolete; "it should be restricted to an altered type and preferentially to the older altered basalts. The melaphyres will then bear somewhat the same relation to basalt that the diabases do to the dolerites, and porphyrites to the andesites." (Geikie). In my descriptions I shall use the term 'trap' as a general name for the dark igneous rocks of the district, both diabase and porphyrite.

[2] Irving and Rominger.



GREAT SUCCESSION OF DIABASE FLOWS WITH INTERBEDDED LAYERS OF CONGLOMERATE.

Cross Section of Keeweenaw Peninsula

Their strike, within the mining district, is from north 26° east to north 81° east, with a variable northwest dip, becoming steeper southward. The accompanying diagrammatic section will give an idea of the geological section across the mining region anywhere between Houghton and Calumet. On the east, sandstone beds abut unconformably against the Keweenaw rocks; these sandstones dip slightly to the southeast, and, by their fossils,[3] are known to be the equivalents of the Potsdam formation of New York, this being the top of the Cambrian. The sandstones on the opposite side of the peninsula, and overlying the Keweenaw rocks in apparent conformity, were considered by Rominger to be of identical age and as having been at one time continuous over the 'trap,' that is, the diabase layers of the Keweenaw series.[4] Pumpelly and Irving thought that this required too much erosion. Wadsworth claimed that the Keweenaw rocks are in places superposed over the eastern sandstone. The matter is further complicated by a vertical plane of demarkation along the contact of the trap series and the eastern sandstone, it being an open question whether this break in continuity is a gigantic fault or merely the cliff marking an ancient shore line. Pumpelly and Brooks held that the eroded conformable downward extension of the Keweenaw series would be found under the eastern sandstone; while Irving and Chamberlain considered that the east face of the Keweenaw series represented a fault-scarp, the downthrown part of the series being under these eastern sandstones. Hubbard holds to the existence of "an eroded line of steeply dipping and somewhat corrugated traps, against whose mural faces and over whose gentle slopes, respectively, the eastern sandstone was laid down."[5]

[3] Found only in the Menominee district.

[4] C. Rominger. 'Geological Survey of Michigan.' Vol. V, Pt. I, p. 92.

[5] 'Geological Survey of Michigan,' Vol. VI, Pt. II, pp. 88–91 and p. 121.

Native copper was first found in the transverse fissures crossing the Keweenaw series at the northern end of the peninsula; there the metal was found also to occur along certain beds of conglomerate and amygdaloid intersected by the vein-fissures. Eventually it was proved that the copper occurred elsewhere, even more generously, in certain members of the series, forming impregnations conformable to the stratification and identified with persistent beds of amygdaloid and conglomerate. The diabase rocks include beds the upper layers of which are amygdaloidal, this structure representing the foamy surface of lava streams. As the pores or amygdules become filled with various minerals a compact rock results, and from a vesicular lava there is produced an amygdaloidal diabase. These pervious beds have become the place of ore deposition, and by reason of similar favorable physical conditions, the conglomerate layers also have been enriched with copper in certain localities so as to afford a basis for profitable mining.

The 'mineral range' of this region consists of a belt from four to six miles wide, constituting the eastern portion of the trappean series, the members of which vary in thickness[6] from a few feet to more than 100 ft., the individual layers being distinguishable, where they are not separated by beds of conglomerate, by the amygdaloidal character of their upper portion. The texture of the trap changes from compact, at the bottom of an individual bed, to vesicular, near the top.[7] Dark green is the prevailing color, save where mineralization has been accompanied by the oxidation of

[6] The 'Greenstone' is a particular bed over 1,000 ft. thick, which may, however, consist of several beds. Van Hise thinks it may have been intruded. Lane considers it to be a series of flows that followed each other in rapid succession. 'Geological Survey of Michigan,' Vol. VI, Pt. II, p. 74.

[7] Occasionally the lower side also may be vesicular, which is quite in accord with what is known concerning the flow of lava streams, the bottom and top cooling rapidly by contact with the cold surface and the cold air, respectively, while the interior retains its heat for a long time. Similar conditions can be observed by watching the dumping of a slag pot.

the iron. Labradorite, and a ferruginous chlorite allied to delessite, are the essential constituents of these traps,[8] but they owe many of their most notable characteristics to metamorphism, in the course of which chlorite has been formed from hornblende or augite, and epidote has filled the amygdules.

Furthermore, these amygdules contain a great variety of minerals, those now seen being chiefly secondary products which have replaced the original occupant of the cavity. Calcite, quartz, laumontite, prehnite, analcite and datolite may be mentioned, beside the epidote and chlorite, and finally there is that most important mineral of all—native copper. This is found crystalline in its own form, but frequently it has the shape of the amygdule which it fills, or, more rarely, it has the form of some other mineral which it has replaced. Both the amygdaloids and the conglomerates are heavily impregnated with epidote. Some of the porous epidotic amygdaloid layers have had copper deposited in them to such an extent as to produce large hackly masses of metal weighing several tons.

The Quincy lode, for instance, is essentially a soft brown and green amygdaloid forming the upper portion of a bed of diabase; the richest part of the lode channel, toward the hanging, represents the upper crust of a lava flow which was vesicular when extruded and is now amygdaloidal through the deposition of minerals, one of them being copper. The overlying bed is a dark, compact, fairly coarse diabase, the dark-red color of which is due to the feldspar. The amygdaloid of the copper lode itself has a minutely crystalline groundmass containing acicular plagioclase and granules of magnetite, which has been oxidized to hematite.[9] The copper is sometimes pseudomorphic after laumontite and is also found enclosed within transparent scalenohedra of

[8] 'The Paragenesis and Derivation of Copper and its Associates on Lake Superior,' by Raphael Pumpelly. *American Journal of Science*, Vol. II, No. 9, p. 793.

[9] R. Pumpelly and C. Rominger.

calcite, the order of formation being laumontite, quartz, copper, calcite and datolite.

The conglomerates frequently enclose seams of fine-grained laminated sandstone, and in such beds an impregnation of copper is not uncommon. As a rule, the pebbles of the conglomerate beds consist mainly of chocolate-colored felsitic porphyrite, the fragments of diabase and its amygdaloid being subordinate in amount. Finer silicious grains of the same material fill the interstices and cement the pebbles together; but this original binding material is now largely replaced by secondary minerals, such as calcite and epidote, together with chlorite and native copper. The conglomerate bed constituting the lode channel of the Calumet & Hecla is from 12 to 25 ft. thick, and dips nor west at from 36° to 39°. For a length of two miles in this mining property there are but few barren spots; and the conglomerate is stoped continuously, save for pillars to support shafts, the average yield of copper being about 2.5 per cent. The rock is reddish brown and so compact that it breaks across the pebbles, which are the detritus of quartz porphyry and granite; the spaces between pebbles are filled with smaller granules bound together by a cement which is both silicious and calcareous. The metallic copper occupies the spaces between pebbles and often entirely replaces the cement; it also penetrates the capillary fractures in the pebbles and, indeed, the replacement has gone so far that even pebbles are turned into copper, the result being "a spongy skeleton of copper in an epidotic rock carrying calcite."[10] The hanging wall of this Calumet & Hecla lode is a dark-colored, fine-grained diabase.

The position and appearance of the succession of diabase beds indicate that they are extrusive sheets of lava; the upper amygdaloidal layers have a surface which is often scoriaceous and contains sand, indicating that their extru-

[10] C. Rominger. 'Geological Survey of Michigan,' Vol V, Pt. I, p. 116.

sion was followed shortly afterward by sedimentation. Likely enough they were extruded under water. It is this sintery appearance which has provoked such local terms as "ash bed."

Movement of the Keweenaw series is manifested by several small displacements in the mines which I visited; but the most interesting evidence of this kind is the occurrence in the Central mine, where the so-called East vein is faulted along the Kearsarge conglomerate, the heave being

AN AMYGDALOID LODE, QUINCY MINE.

284 ft.; a dislocation which, as measured in terms of the displacement of the rocks lying above the Kearsarge conglomerate, has been estimated as equivalent to a movement, horizontally northward, of more than 2½ miles.[11]

The distribution of the copper, as observed in the mine workings, is seen to be dependent upon the structure of the rock. In the Quincy the "main hanging wall" is marked by a slip or parting, of variable definition; back of this there is a band of shaly trap, which is apt to become troublesome by creating shaky ground. The lode itself is a brown amygdaloid with earthy fracture, spotted with amygdules consisting

[11] L. L. Hubbard. 'Geological Survey of Michigan,' Vol. VI, Pt. II, pp. 88–91.

of green chlorite, white calcite and red laumontite. Copper occurs on quartz and pseudomorphic after laumontite. Chlorite is found distributed over both quartz and copper, penetrating the former. The calcite, which contains bright native copper, often tends to arrangement in lines, giving the lode occasionally a streaky appearance. The rock is often vesicular, especially close to the 'hanging,' owing to void cavities. Capt. Thos. Whittle informed me that the lode is usually dry, but that moist places are richest.[12] This simply means that in such portions of the lode the rock is less tight, possibly more vesicular, and permits of the descent of water through the interstices. The accompanying sketch (page 28) illustrates the general structure of the Quincy bed.

At the Atlantic, the copper is fairly disseminated from hanging to foot, that is, throughout the amygdaloid which constitutes the lode. Occasionally the richer rock favors one or the other wall, and rarely the copper spreads beyond the hanging wall into the overlying trap. Cross-joints produce 'floors' which make trouble in mining. It is found advisable occasionally to leave a width of copper rock rather than "leave the hanging bare." When the lode is narrow it still carries about the same amount of copper per linear foot, so that it is richer per ton than where it is wide; when narrow, the ground is apt to be tight. On the foot-wall there is a 'flint rock,' a close-grained jaspery amygdaloid, but the bulk of the lode is a chocolate-colored rock, rich in laumontite. The amygdules are little museums. In a single amygdule one can distinguish the successive deposits of laumontite, copper, chlorite, calcite and epidote. The cavities now filled with these minerals appear to be long vesicles due to the expansion of water vapor or gas. Near

[12] In one place in the mine where a considerable flow of water enters through the foot-wall, metallic copper is now being deposited in notable quantity. And who can say but that a very slow precipitation may not be going on where the rock is moist only in the lower levels of this mine?

D shaft on the 31st level, I saw a cross-course, a band of fracture extending across the lode and rendering it barren for a length of 40 to 50 ft. This transverse vein carries more calcite than the lode itself.

The distribution of copper in the Baltic mine is particularly irregular. The lode channel appears to be a sheared zone with a system of fracturing which has reached beyond the limits of the particular amygdaloidal layer, and into the encasing trap. Movement is indicated by slip-planes and cross-joints, especially a system dipping flatly southward. Occasionally slips dipping toward each other tend to form wedges of rock which make dangerous ground. Selvages are observable. At No. 4 a vein 4 to 5 in. wide exhibits this evidence of movement and crosses the lode channel for a distance of 200 ft.; it carries copper, with quartz and calcite. Most of the cross-veins, which are frequent, do not extend beyond the lode limits, and they are short-lived in any direction. Their strike usually conforms to that of the main lode channel, but in one of the upper stopes I saw a seam of chalcocite, in the foot-wall, dipping away from the lode. This seam was $\frac{3}{4}$ to 1 in. thick, enclosed within quartz. Specimens showing deposition of chalcocite on native copper also occur in this lode. In going through idle workings which have been extended in rich ore, one can see the metallic copper sticking out, though it is tarnished black by the nitrous fume generated by the explosives used in the mine. The superintendent will pass his hand over the face of a working for the purpose of estimating the percentage of copper, the projecting rough edge of metal furnishing an index sufficient for an approximation of the average content.

In the Wolverine, wet ground is a good sign. Capt. William Pollard stated that "where there is water there is copper somewhere around." This confirms the experience of the Quincy, the best-producing ground being where the rock is vesicular, damp and inclined to be soft. The

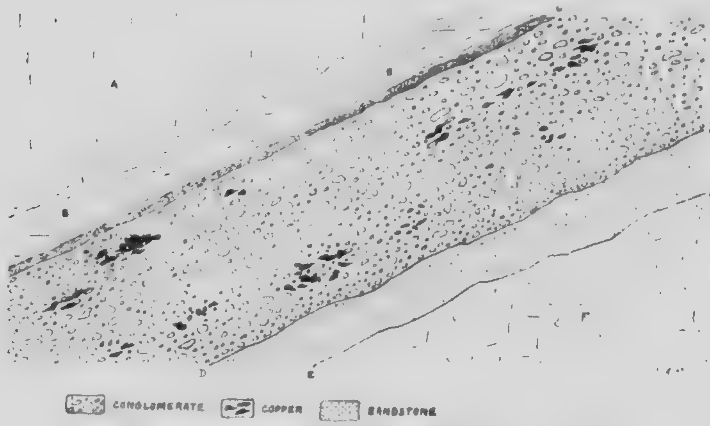
so-called 'walls' of the Wolverine are at best but ill-defined boundaries. A persistent soft seam separates the reddish soft lode from the harder greenish-gray trap overlying. Copper is found extending into both walls. I noted sheet copper along cross-joints in the foot-wall; this is said to occur in the hanging also. The rock nearest the hanging is most amygdaloidal and is usually richest. In many places the presence of lump copper can be seen at a distance by reason of patches of light-colored decomposed rock. Nests of metallic copper occur in this soft matrix. The laumontite lines the amygdules and encloses calcite, while the copper is found replacing both of them.

Joints and long slip-planes cross the lode at a strong angle; these are apt to mark a change in the copper content. If the rock is poor it becomes richer on the other side, or *vice versa:* this, however, is only a local effect. Several cross-courses are encountered. They consist of bands—from a few inches to two feet wide—of barren shattered rock streaked with seams of white calcite. They appear to disturb the copper lode only slightly, not enough to affect mining disadvantageously. Copper is rare in these cross-veins, and then only close to the crossing. At the 25th level there was a boulder in the hanging, which looked as if the trap had flowed into a hollow in the surface of the amygdaloid, that is, as if hot lava had been extruded over the cold vesicular surface of an earlier flow.

It may be stated in a general way that the mineralization of the amygdaloidal lodes is diffused and irregular; the upper or hanging-wall limit to the profitable rock is occasionally fairly clear, but the foot is not. In the early days it was the great maxim of Capt. Daniell and other authoritative mine managers to "keep to the hanging"; and the custom was to run little drifts, which followed the course of the hanging, no matter how the lode might turn and twist. This is no longer the practice, for it is recognized that the distribution of the metal disregards supposititious walls;

and, in order to extract it properly, a less narrow scheme of exploration is required.

The conglomerate lodes are better defined, as will be illustrated by the Franklin Junior mine, which I visited under the courteous guidance of Capt. John Doney, and Mr. F. W. Sperr, professor of mining at the College of Mines. This mine is on the Boston and Albany conglomerate, which is the same as the Allouez conglomerate. At the 375-ft. level I saw the section reproduced on this page. Under the outer



A CONGLOMERATE LODE, FRANKLIN, JR., MINE.

body of hard trap constituting the hanging-wall country, there are 4 to 5 ft. of shattered trap; and between this and the conglomerate there is about one foot of flucan. This soft stuff varies in different parts of the mine from a mere selvage to a thickness of four feet. The copper-bearing conglomerate itself is from 8 to 25 ft. thick, narrowing northward and widening southward. Underneath it there are 3 to 4 ft. of sandstone, and below this comes the amygdaloidal trap of the main foot-wall country. The conglomerate breaks clean from the foot-wall sandstone; the latter shatters in slips, which make bad ground. In order to avoid the flucan in the hanging and decrease timbering

expense, it is the custom to leave 4 or 5 ft. of conglomerate to support the ground, the value of the copper lost in this way being less than the expenditure otherwise required for extra timbering. As the successive levels are exhausted and abandoned, this shell is removed. The flucan is a breccia-selvage, a clay containing broken pieces of trap. Beyond it there are several feet of shaly ground which looks like a volcanic dust that has been deposited in water and subsequently consolidated. The lode is traversed by well-marked joints and slips; they are as well defined as the walls.

The reddish-brown feldspars of the porphyrite, constituting the principal detritus of which the conglomerate is built, give it a chocolate tinge. The pebbles range from the size of a pigeon's egg to that of a turkey; the largest boulders are as large as a man's head. When the conglomerate is not too coarse, it is most favorable to copper, probably because the interstices between the larger boulders are filled with fine sand, which renders such a rock less per meable to mineralizing solutions. In hard ground, that is, where the conglomerate is so consolidated that it breaks across the pebbles, these cross-joints are prominent and make big, blocky ground. The best ore is in the looser conglomerate, where the fracture planes show projecting pebbles instead of clean-cut surfaces. Here, as in the amygdaloid lodes, the copper favors the permeable rock. No copper is found in the foot-wall sandstone; in the deeper levels, however, where the sandstone has thinned out, the conditions change, and copper extends from the conglomerate of the lode into the underlying amygdaloid. Here also there is an obvious connection with permeability, the closely cemented sandstone offering a bar to diffused mineralization. The sandstone is a reddish, laminated rock; at surface it crumbles quickly on weathering, on account of its calcareous binding. Occasionally sandstone makes its appearance within the conglomerate, and is found per-

sisting for a couple of hundred feet, with a maximum thickness of seven or eight inches. Fine particles of copper are found in this sandstone, which differs in character from that on the foot-wall. There are also nodules of copper scattered through the flucan, and in the overlying trap a little flaky copper is found. At the 18th level—about 1,850 ft. from surface as measured on the 48° dip—the conglomerate lode lies on the amygdaloid; the latt r has a humpy, billowy surface, and the parting between it and the conglomerate is tight, that is, the two beds adhere.

III. — Early History.

In 1903 the copper mines of Lake Superior yielded 192,29[illegible] lb. of refined copper,[13] this being about 15 per cent of the world's production; therefore no excuse is needed for a sketch of the historic development of the region. This account will be more readily understood in the light of the geologic description which has already been given. The geologic features of a mining country bear a relation to its development similar to that of geographic conditions in the history of the nations.

The first account of the occurrence of native copper near Lake Superior is found in a work by Lagarde, published at Paris in 1636. Reports by the Jesuit missionaries and early *voyageurs* make mention of it, and in 1666 Claude Allouez gave details. These French Jesuits were the first white men in the region, and, according to their accounts, the Indians had been mining copper before the Europeans came. A century later, in 1763, a practical Englishman, Alexander Henry, who had come to North America soon after the conquest of Canada by the British, passed through the region; and in 1771 he began mining operations, but with so little success that he desisted in 1774. In his 'Travels,' published in 1809, he mentions a mass of copper which he found near the mouth of the Ontonagon river. This is the mass now to be seen at the Smithsonian Institution.[14]

Another period of silence supervened; for seventy years there was no progress. The pioneer of the great mining activity in the Lake Superior region was Douglass Houghton, the first State geologist of Michigan, who was appointed in 1837. At that time the salt springs of Wyandotte

[13] The production for 1904 was 206,800,000 pounds

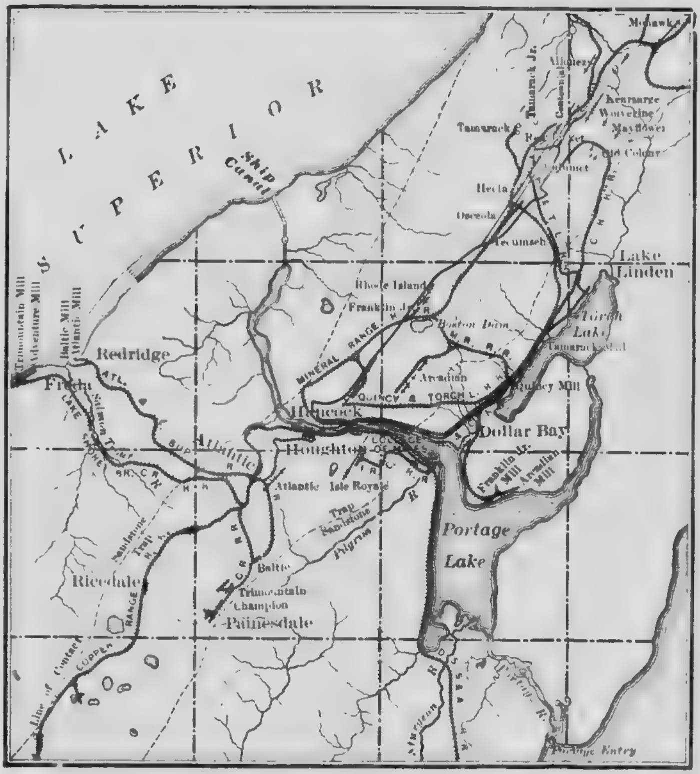
[14] See page 99 and frontispiece.

county (in the vicinity of Detroit) constituted the principal mineral industry of the State. In the summer of 1839, Houghton made extensive explorations; and in his fourth annual report, submitted in February, 1841, he gave a scientific description of the copper deposits. It is evident, however, that at first he regarded the metallic condition of the copper as an indication unfavorable to permanence, and he held this view until he found "that feature was more or less universal with respect to all the veins." He brought back four or five tons of copper to Detroit, for analysis.

No mining operations were begun at this time, but Houghton's reports had drawn attention to the region; and, upon the cession of the land to the United States by the Chippewas, on March 12, 1843, there followed a speculative craze which lasted for three years. The lodes described by Houghton, and those actually opened up in 1844 by Charles T. Jackson, who was the first to test their value by mining, were the veins of the Eagle River district, near Keweenaw Point. These carried both native silver and native copper, not in the layers of conglomerate and amygdaloid, which became the great producing lodes of later years, but in transverse veins cutting across the bedded series of rocks. Of these the Cliff was the principal; it was discovered in 1845, and was examined by Jackson and also by Whitney, both of whom advised exploration at the foot of the cliff, on the crest of which evidence of a copper deposit had been found. An adit was started at the base of this bluff; and at 70 ft. it cut a body of metallic copper, the first 'mass'—as such occurrences are termed—found by systematic mining in the Lake Superior region. The discovery was important, because it indicated that the erratic boulders of metal, previously found in the district, had their origin in the lodes and not in foreign sources.

The Cliff mine exploited a fissure, which, in cutting 'across country,' intersected several amygdaloid beds, some

of which proved to be productive for a distance on either side of the main vein; these were known as 'floors' and 18 of them were mined profitably. The mine, almost from the start was remarkably rich in 'mass.' Between 1846 and 1853, the sales of copper netted \$1,328,406, the divi-



MAP EXHIBITING THE POSITION OF THE PRINCIPAL MINES.

dends during that period aggregating \$462,000. The depth attained was 462 ft., and the range of development about 1,200 ft. In 1870 work was discontinued, owing to impoverishment at the bottom levels; up to this time the mine had paid its stockholders \$2,627,660 or a little over

2,000 per cent on the paid-up capital. In 1872 the mine was reopened under a new organization, and the output rose again, to 1,162,873 lb. copper in 1875; after that there was a dwindling away, until production ceased entirely in 1887. This mine is now idle.

In 1854 the Central vein was discovered by John Slawson, the agent of the Cliff, who stumbled upon an ancient excavation in which a large mass of native copper was uncovered. This was sent to Detroit to be smelted. In 1865 the production exceeded a million pounds of copper; and the mines produced steadily until, in 1876, the output reached 2,161,400 lb., and in 1886, 2,512,886. But in 1895, at the 31st level, the vein was found to be cut off by a bed of conglomerate; its faulted prolongation downward is supposed to have been recognized, but it was barren of copper.

In the meanwhile, at the south end of this copper country, the mines of Ontonagon were doing well. The principal mines were the Minesota,[15] National, and Mass. The Minesota was discovered in 1847 by S. O. Knapp, who noted the surface indentations due to ancient workings. In one of these, at a depth of 18 ft., he uncovered a mass of native copper weighing six tons; this evidently had been moved at some bygone period, for it lay five feet from the lode and had been supported on timbers, rotted remnants of which were found. The first shipment from this mine was made in 1848, the year in which the first company was organized. Dividends, aggregating $1,920,000, were paid up to the end of 1881. Nearly 70 per cent of the product up to 1861 was in the form of 'mass,' and only 6 per cent was 'stamp-rock.' The mill was a crude affair; and, when the masses became scarce, the company had to shut down, in 1870.

The National company opened up the location adjoining the Minesota; and the two companies gave the Ontonagon

[15] The name of this mine was Minesota, although the State is Minnesota.

QUINCY, NO 2, ROCK-HOUSE

district a wide celebrity for twenty years, both by reason of their production and through the fierce litigation in which they became involved. The National began work in 1848, and for 23 years it maintained a steady output. Up to 1871 this mine produced 5,000 tons of copper, worth $2,295,231. Operations were on a small scale, and the owners showed lack of enterprise. In 1871 the workings were turned over to tributers, who gophered for a while, before work ceased entirely. In 1881 the mine was unwatered and fresh explorations were started, under the able direction of Capt. E. W. Parnall, who afterwards became so well known at the Tamarack. The nature of the production in the early days is indicated by the fact that in 1864, 385 masses yielded 433,458 lb. copper; and in 1865, 318 masses yielded 516,244 pounds.

Prospectors early found their way southward from the Eagle River mines to Portage lake. The riches of the district, now known as Calumet, were unsuspected at that period, and it was nearly twenty years before they were discovered. The country around Portage lake was easily accessible, and a settlement was formed in 1847.[16] In that year also the first of the bedded formations was uncovered, and this discovery formed the basis for the organization, in October, 1848, of the Quincy Mining Company; but the early exploration of this part of the district was not promising, because it was directed largely to the fissures. For a year the Quincy company fussed over one of these worthless cross-veins, before the discovery of a rich bedded lode formation was made by the Pewabic, a company organized by C. H. Palmer in 1848. The Portage district underwent no serious exploration for several years, greater activity being displayed in the Eagle River and Ontonagon districts. In 1852, however, the Isle Royale lode was found just behind Houghton, and large quantities of native copper were ex-

[16] Graham Pope, *Proceedings* Lake Superior Mining Institute, Vol. VII, pp. 18-31.

tracted with a success that made this mine famous—and with it, the locality. Adjoining tracts of land were quickly taken up; and in 1853 the Huron Mining Company was organized at Boston, although the extension of the Isle Royale lode was not actually found until the year after. At this period Cornish miners began to arrive, attracted by reports which had reached England, and their names begin to appear in the later records. In 1854 and 1855 mining matters around Portage lake looked gloomy; some of the mines, like the Quincy, had not yet found the lodes which subsequently made them so productive, and they were struggling along, exploiting the poorer layers of amygdaloid (which are parallel to the rich lodes) and the thin cross-veins, as already mentioned. In 1856 the Pewabic company found the great amygdaloid lode known by that name; and the neighboring mine, the Quincy, promptly followed suit, at a time when hope and money were both at a low ebb. During 1856 the Quincy produced 13,462 lb. copper; but not until 1860 did the mine become profitable. In 1873 the yield was 2,800,005 lb.; in 1883, 5,549,087 lb.; in 1903, it was 18,498,288 lb. refined copper. The Quincy has paid dividends aggregating $14,620,000, upon a capital of $2,500,000.

The first copper mines in the Lake Superior region, as we have seen, were on the veins of the Eagle River district, which cut *across* the bedding of the trap, amygdaloid, and conglomerate constituting the prevailing formation. These discoveries were closely followed by development of the lodes of 'mass' copper in the Ontonagon district, at the south end of the region, where the veins cut the bedded series *at an acute angle* on the dip. Subsequently came the opening up of rich copper deposits in the *amygdaloid* layers, such as the great Quincy mine. Finally, the uncovering of a copper-bearing *conglomerate* marked the birth of another momentous development. Such was the discovery of the Calumet lode by E. J. Hulbert, John Hulbert and Amos H. Scott, in September, 1864.

IV.—Calumet & Hecla.

The recital of the events connected with the uncovering of the Calumet & Hecla lode forms a story by itself. It does credit to the persistence of the discoverer, Edwin J. Hulbert, and to the shrewdness of his financial supporter, Quincy A. Shaw; but it is marred by one of those not infrequent misunderstandings between men of unlike temperament, resulting in the familiar dispute as to whether the man who finds, or the man who founds, a great mine should be the chief beneficiary. Hulbert was a surveyor; he had laid out roads, and mapped lands and mine workings, for ten years before the discovery. He has related[17] how, in 1853, he lived in the Eagle River district and became a keen student of mining geology under such veterans as W. H. Stevens, Samuel W. Hill and Chas. Whittlesey. At that period, mining for copper in the bedded series was not recognized as promising profit, and all the work was concentrated upon the transverse veins of the district. In 1858 he began the survey of a State road from Copper Harbor to Ontonagon, and in the course of his work he noted a violent deflection of the magnetic needle on Section 23; this put him on the alert for a mineral discovery later. While making the northern portion of this survey, he found fragments of a brecciated conglomerate containing copper, similar to 'float' encountered by him several years earlier on the banks of Eagle river. The conglomerate differed from any other in the district by being brecciated, and it was this fact that started him on a long and persistent search.

In making a final survey for the road from the Cliff to Portage lake, he picked up some fragments of this conglomerate, and shortly afterwards he discovered a big block of it,

[17] 'Calumet Conglomerate, an Exploration and Discovery made by Edwin J. Hurlbert, 1854 — 1864.' Pamphlet, *Ontonagon Miner Press*, 1893.

covered with moss; also, not far away, he observed a depression which he took to be an ancient pit, similar to others previously known elsewhere in the Keweenaw peninsula. Upon examining the map, he found that this was on government land; therefore, in February, 1860, he bought a tract of 1,920 acres, so located as to cover the ground in which he purposed to explore for the copper-bearing breccia-conglomerate. In July, 1861, he deeded a three-quarter interest in this land to J. W. Clark, Horatio Bigelow and other Boston men. The civil war came, mining activity languished and nothing was done until 1864, when this tract became the basis for organizing the Hulbert Mining Company, in which he was allotted 5,000—out of 20,000—shares. Meanwhile, in June, 1859, Hulbert, Amos H. Scott (who worked for him), and the old explorer, W. H. Stevens, found the Allouez conglomerate. This led to the formation of the Allouez Mining Company, with Horatio Bigelow as secretary. But the work done during that winter sufficed to prove the poverty of the lode. All subsequent attempts to work this conglomerate have failed likewise; but now, 45 years later, the Allouez company appears destined at last to become a successful mine by exploiting the Kearsarge amygdaloid, which, on its dip, traverses this property between the Wolverine and the Mohawk mines. A shaft is being sunk to cut the lode at an estimated depth of 1,100 feet.[18] That the Kearsarge amygdaloid was not discovered then, is small wonder, for Hulbert and Scott tried to find the extension of the Quincy amygdaloid, where it would cross this tract east of the Allouez conglomerate; they failed, because of the thickness of the soil and the swampy nature of the ground.

After the Allouez enterprise failed, and the civil war disorganized business, Hulbert himself remained away from

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[18] Recently a drill-hole from the shaft has proved the lode to be steeper than supposed, so that the shaft will not cut it until a depth of 1,400 ft. is attained.

the district, partly owing to a severe illness, until, in 1862, he returned to do survey work at the mines near Houghton. In May, 1864, he became superintendent of the Huron mine. In July, of that year, he re-visited the site of the conglomerate boulder in the forest, and found everything undisturbed. Having determined to search anew, and with more system, for the long-sought copper lode, he wrote to Bigelow, of the Hulbert Mining Company, to purchase more land. This was done, the price being $35 per acre, for 200 acres. Immediately thereafter he chose a point of attack (the site afterward of the Calumet No. 4 shaft), and on September 17, 1864, his brother John and Amos H. Scott, working under his direction, cut through the amygdaloid forming the hanging wall, into the copper-bearing conglomerate. Winter coming, work shortly ceased. A barrel of specimen rock was sent to Boston on November 15, 1864. In the advice of this shipment it was suggested that another company [illegible] formed to take the land in Section 13, held by the Hulbert company; and this was done, in December, under the name of the Calumet Mining Company of Michigan. This company was organized on a basis of 20,000 shares; in the same month the Hecla Mining Company was also formed, with an equal capitalization. In the spring of 1865 he went to Boston and there met Quincy A. Shaw, arranging with him a loan of $16,800, wherewith to buy additional land; this was deeded to the Calumet company; and he received 5,833 shares, making his holding 10,833 shares in the 20,000 shares for which the company was organized.

Meanwhile, in 1865, exploration of the ancient pit (noted long before by Hulbert as occurring near the discovery of the conglomerate) had proved that it was not a prospect hole nor a pit sunk on a copper lode, but an Indian hiding place or 'cache' in which was found a mass of copper, unaccompanied by tools of any sort, such as would suggest former mining; but there were found birch-bark baskets

THE TOWN OF CALUMET. CALUMET & HECLA AND TAMARACK MINES

used for carrying copper, also pieces of Indian-tanned deerskin, such as is employed for repairing moccasins, and other articles, proving it to be no mine opening. Over 50 barrels of copper carbonate were taken out of this excavation, this being the weathered remnant of copper which had been secreted there by the former diggers. In February, 1866, the pit was cleaned out; and, on sinking through the floor of it, the amygdaloid overlying the Calumet lode was penetrated, and conglomerate exceedingly rich in copper was encountered. The 'cache,' therefore, was close to the lode, but not on it, being on the hanging wall side. Hulbert at once sent word to Mr. Shaw to secure the refusal of Section 23, covering the ground which it was obvious the lode traversed in its strike southwestward. This section was part of the territory belonging to the St. Mary's Canal Mineral Land Company. The United States Government had granted the State of Michigan 500,000 acres of mineral land in the Upper Peninsula for disposal to the company which should build the canal connecting the St. Mary's river with the basin of Lake Superior. This grant became the basis for the organization, in 1858, of the St. Mary's Canal Mineral Land Company, which forthwith began the sale of lands, and remains to this day a large proprietor of mining territory, being also a half owner in the Champion mine, as will be related later in this account. Section 23 was bought from the Canal company for $60,000; and Hulbert was allotted one-third of the 20,000 shares of the Hecla Company, which acquired it, the remaining two-thirds being held by Mr. Shaw and his brother. Thus Hulbert was able to lay claim to having selected every acre of the mining land held by the Calumet & Hecla.

The Calumet Mining Company was organized with a capital of 20,000 shares, having a par value of one dollar. Toward the close of 1865, the reports of the richness of the lode became noised abroad; and the stock rose by successive jumps, until in July, 1866, it was quoted at $75 per share.

An assessment of $5 was made to raise working capital; and this assessment was followed by others, making a total, up to that time, of $12.50 per share. The absence of mass copper, and the supposed difficulty of treating the ore, caused the shares to fall heavily, and many of the local stockholders sold out—to their lifelong regret; indeed, before the

A MAIN LEVEL IN THE CALUMET & HECLA MINE

profit-earning stage was reached, there was much financial embarrassment, by which Hulbert suffered seriously. What with assessments and loans, about $1,200,000 was required before the mine became a profitable undertaking; all the original owners in the Calumet & Hecla enterprise being severely put to it to provide money to develop the mine until it earned profits. Hulbert lost a large part of his

interest by having to exchange it for debt certificates of the Huron mine, of which he was the manager. This embittered him, naturally enough; there was a quarrel with Quincy Shaw and the Boston directors; but about twenty years ago a settlement was made with Hulbert, he receiving $300,000 in Calumet & Hecla stock, which was placed in trust. The income from this supports him comfortably; Mr. Hulbert is now living at Rome.

The Hecla paid its first dividend, of $5, in December, 1869; and the Calumet, in August, 1870. The two companies were consolidated in May, 1871, the Portland and Scott companies being included; the Calumet & Hecla was then organized with a capital of $1,000,000, in 40,000 shares. At that date the dividends of the united mines had already amounted to $2,800,000. In 1874, 230,000 tons were treated, at a cost of $7.40 per ton, yielding 4.28 per cent copper; in 1875, 239,000 tons at a cost of $5.82, yielding 4.33 per cent.

In 1879 the capital stock was increased to $2,500,000, or 100,000 shares of $25 each, this being the limit allowed by the laws of the State of Michigan. In 1881, eleven shafts had been sunk and an estate of 1,720 acres had been consolidated. The dividends that year amounted to $2,000,000. It may be interesting to quote the list of the mines which were paying dividends at that time, 23 years ago; they were:

	In 1881.	Dividends up to the end of 1881.
Atlantic	$80,000	$260,000
Calumet & Hecla	2,000,000	21,350,000
Central	60,000	1,664,000
Osceola	225,000	385,000
Quincy	440,000	2,810,000

At the end of 1882 the Calumet & Hecla had taken copper valued at $71,219,610, out of ground equivalent to 120 acres. In 1883 the average width of stope was reported[19] as 8 ft., with a maximum of 20 ft., and an average yield of 4.5

[19] Chas. Kirchhoff. *The Engineering and Mining Journal*, July 12' 1884.

per cent copper. The mine made most of its water between the 14th and 18th levels, being so dry at the bottom, then at 3,000 feet, on the lode, that water had to be taken to the drillers. The levels were 93 ft. apart on the dip, or 60 ft. vertical. The company owned 13,335 ft. on the strike, embracing practically all the known rich part of that particular conglomerate bed. It was recognized at that time, as it is now, that the Calumet & Hecla is not representative of the region, because it possesses a lode so rich that there is no other mine to be compared with it, either in amount of production or in extent of profit. The expenditures and methods of this company would have killed any ordinary mine; apparently, the management, in the past especially, has had no need to aim at economy, and evidently it did not, although it does now. The Calumet & Hecla has paid dividends to date aggregating $86,350,000 on a capital of $2,500,000, par value.

V.—Later History.

At the south end of the Calumet & Hecla, the lode is worthless, except adjacent to the Hecla boundary; and to the north, on the Schoolcraft addition, a company was ruined in an effort to work that extension of the Calumet lode. Here is the place to tell the story of the Osceola mine.

The Osceola Consolidated Mining Company was organized in 1873; it was based upon a consolidation of ground owned by J. W. Clark and Wm. Stewart, respectively; the stock was placed among a few subscribers by Horatio Bigelow and Joseph W. Clark, of Boston. E. J. Hulbert was put in charge of operations, and a mine was opened near the southern boundary of the Calumet & Hecla ground. These facts caused the company to become well advertised, so that the stock was eagerly taken on the understanding that the discoverer of the Calumet & Hecla had found "another conglomerate belt" of similar richness. The Osceola at first was supposed to be a lode different from the Calumet, its discovery being based upon some erratic boulders of conglomerate rich in copper, found lying on the surface. But the borings, and other exploratory work undertaken by the new company, were unsuccessful; and, when it became known that the Osceola was really working the extension of the Calumet conglomerate, there was a great deal of disappointment. The mine, opened on the Calumet & Hecla lode, proved, however, to be fairly productive at first; but the progress of development assured ultimate failure, for the Osceola owned only a short end of the rich ore-bearing ground of its great neighbor. In this emergency, it fortunately happened that an amygdaloidal copper bed was found 800 ft. east of the conglomerate, and steps were taken forthwith to test it. This exploration was begun in 1877, and four shafts were sunk in the course of the next three years. In 1877 the production was 2,774,777 lb. copper,

and it rose steadily to 6,894,256 lb. in 1892. Up to date this company has disbursed $4,439,600 in dividends, on a capital of $2,500,000.

Next we come to the story of the Tamarack, one of the best in the records of mining. In 1880 the Calumet & Hecla had

HEAD-FRAME, TAMARACK, No. 2. SHAFT.

gone down 2,500 ft. on the lode; and it required only 1,000 ft. more to reach the boundary between this property and the Tamarack, which adjoined to the west, that, is on the dip side. The Tamarack enterprise was the 'deep level' of the Calumet; and, while the idea of sinking a vertical shaft 2,250 ft. to intercept a lode dipping out of the ground owned by an outcrop company, is now a common form of mining

enterprise at Johannesburg, it was a new and courageous plan to adopt, twenty-four years ago, when Horatio Bigelow, Joseph W. Clark and John Daniell started to carry it out. Capt. John Daniell gave the reason for the faith that was in him in words which are worthy of quotation: "The Calumet & Hecla Company divides $2,500,000 among its stockholders annually, and the very important improvement of late years would absorb a further expenditure of $500,000; for the machinery erected is of the most costly character, while it seems large enough to reach any required depth. The receipts, then, beyond running expenses, would be, say, $3,000,000. The amount of rock treated in the stamp-mills does not exceed 1,000 tons per day, say 370,000 tons yearly. Therefore, $9.30 is the profit obtained per ton of rock.

"When it is understood that the Atlantic and the Franklin mines earn less than $1 per ton on rock treated, the Osceola less than $1.50, and the Quincy mine, in her most prosperous year, less than $4 per ton, and then on about one-third the quantity of rock, it will be seen that the effort to get a share of these unusual (in copper) profits, is prompted by very strong incentives."

The Tamarack property was organized with an estate of 1,280 acres. The first shaft was started in that corner of the company's property which afforded the shortest vertical distance to the lode. The work of sinking was begun in February, 1881, and on June 20, 1885, the lode was struck. During these 4½ years, the lowest rate of sinking was 42 ft. per month, and the highest 70 ft. The total depth was 2,270 ft.; the cost, all expenses included, amounted to $61 per foot. At 600 ft., the shaft cut the Allouez conglomerate; at 2,100 ft., the Calumet & Hecla conglomerate; and at 2,700 ft., the Osceola amygdaloid. In 1885 the production of copper was 181,669 lb.; and in 1886 it was 3,646,517 lb., increasing to 7,405,606 lb. in 1887, and 11,409,217 lb. in 1888. In that year, 1888, the first dividend, amounting to

$640,000, was paid on a nominal capital of $1,000,000. The capital was increased to $1,250,000 during the spring of 1890, and to $1,500,000 in 1896. Up to date the dividends distributed aggregate $8,580,000.

The Wolverine, before its present era of success, had been opened up in a small way by local people, who operated one stamp, treating 100 to 150 tons per day. But the enterprise ran in debt. There was also a conflict of title, two patents having been issued to the same piece of land. Mr. John Stanton, becoming favorably impressed with the business, organized a company and pumped out the mine; but he found that it had been well gophered by tributers. He opened up new ground, and started crushing in September, 1891; but soon realized that the average yield was insufficient to give profits when working on a small scale. Crushing ceased on April 1, 1892. Production having ceased, Mr. Stanton again proceeded to open up the ground vigorously· and after 13 months, a second start was made, in May, 1893, with one stamp treating 250 tons per day. In 1897 another stamp was leased at the Allouez mill. Since then progress has been continuous, and the mine has proved increasingly profitable. From 250 tons, the daily output has increased steadily to 1,000 tons *per diem;* the property has been built up gradually, the cost of more territory, new stamp-mill, and equipment having been met out of earnings. The Wolverine has paid $1,770,000 in dividends on a nominal capital of $1,000,000, of which $550,000 was paid in property and $230,000 in cash.

The existing Atlantic Mining Company was formed in December, 1872, by a consolidation (of a former company of the same name, owning the South Pewabic mine) with the Adams Mining Company, the joint capital being $1,000,000 in 40,000 shares of $25 each. The old mine, known as the South Pewabic, had been ruined by the leanness of the lode. After exhausting its capital stock and spending half a million beside, the company had gone into

kruptcy, and the new Atlantic company was organized. This new organization benefited by the work done by its predecessor, which, failure as it was, had opened up the mine so as to demonstrate the uniformity of the lode and determine its average yield; moreover, the South Pewabic company had built a stamp-mill by the lake and had paved the way—with gold, rather than with copper—for its more businesslike successor, by the accomplishment of a good deal of the essential preliminary work. The Atlantic produced 863,366 lb. copper in 1873, and 1,372,406 lb. in the year following, increasing its production steadily until, in 1888, it reached 3,974,972 lb. In 1902 the 30-year charter expired, and was renewed for a further 30-year term, the capital being increased concurrently from $1,000,000 to $2,500,000. Early in its history this mine won a reputation for cheap working, and it has long been recognized as winning a profit from the poorest copper rock exploited successfully by man. In 1902 the average yield was only 11.10 lb. refined copper per ton of ore stamped, this being equivalent to 0.555 per cent, on a total output of 4,949,366 lb. refined copper. In 1903 the yield was 12.76 lb. per ton on a yield of 5,505,598 lb. copper, from 431,397 tons of rock. Total costs were $1.347 per ton, equivalent to 10.86 cents per pound of copper, which during that year was worth 13.12 cents per pound. The lode is a bed 15 ft. wide, of comparatively soft amygdaloid, in which the native copper occurs with such uniformity as to facilitate exploitation. The conditions which have contributed to the splendid work done at this mine, will be discussed in their proper place.

VI.—Copper Range Consolidated.

The Mineral Range railroad, connecting Houghton with Hancock, was completed in 1873; while the Duluth, South Shore & Atlantic reached Houghton in 1883. In 1885 Hancock and Houghton were connected by rail, over the drawbridge.

Of recent mining enterprises in the Lake Superior copper region, the most important is the Copper Range Consolidated Copper Company. This organization came as the indirect result of efforts, begun by Mr. C. A. Wright as long as fifteen years ago, to bring about the construction of a railroad which should traverse the copper belt south of Houghton, and connect that town with the Chicago, Milwaukee & St. Paul railroad at Mass City, a distance of 41 miles. Owing to untoward circumstances, such as the panic of 1893 and the Spanish-American war, the plan failed until, in the summer of 1898, when, the imminent end of the war stimulating the financial market, Mr. Wright conceived the idea of combining the mineral lands controlled by the South Shore Mining Company, others owned by Mr. S. L. Smith and the Douglass estate, together with a large acreage belonging to the St. Mary's Canal Mineral Land Company, making in all a solid block of 11,500 acres. This plan was subsequently modified; no lands of the Canal Company were included. The first offer of assistance from that company was a subscription of $100,000 to the stock of the railroad, but at the time of the Spanish war this offer was withdrawn; and, after the war was over, the arrangement was changed to a bonus of 2,240 acres of land for the completion of the road, which it was apparent would develop the other large tracts of land owned by the Canal company on the South Range.

Thus the organization of a mining-and-development company was finally carried out as the principal motive for the

construction of a railroad, which should not only connect with the main line of the Chicago, Milwaukee & St. Paul railroad, but should also serve as the chief artery of the copper country from Mass City to Calumet. Among the projectors of, and chief contributors to, the fulfilment of the plan initiated by Mr. Wright, were Mr. W. A. Paine, of the brokerage firm of Paine, Webber & Company, Boston, and Mr. R. R. Goodell, the agent at Houghton of the Canal company.

On January 20, 1899, the Copper Range Company was organized, with a capital of $2,500,000 in $25 shares,[20] to build the railroad and to acquire 7,500 acres of mineral land, with the offer from the Canal company of 2,240 acres, conditional upon the completion of the railroad. The last spike was driven on December 27, in the same year, 1899, and the bonus mentioned was duly paid. In May, Dr. L. L. Hubbard, in charge of exploratory work, discovered a rich copper lode on the new company's territory; and this led to the combination of 600 acres of the Copper Range land, with an equal acreage belonging to the Canal company, the 1,200 acres becoming the basis for the organization, in October, of the Champion Copper Company. From the very beginning this mine made a good showing.

The Champion and Baltic mines cover the same lode. When the lode was discovered by Dr. Hubbard on the Champion land, it had already been proved valuable by the workings of the Baltic. The original openings extended for nearly a mile, and they were of such promise that operations on a large scale were planned with confidence. The lode proved to be richer than any in the region, except the Calumet & Hecla. In January, 1902, the Champion company leased one of the Atlantic's stamps; later in the year its own mill, of three heads, was ready. These milling operations tested the 120,485 tons of copper ore broken in the course of

[20] This is the usual capitalization of a Michigan mining company, and is the maximum allowed by the laws of the State.

THE SOUTH RANGE IN WINTER.

exploratory work. The yield was 4,165,784 lb. copper, or an average of 34 lb. per ton. In 1903 the output was 398,082 tons, which yielded 16,438,184 lb. refined copper, an average of 29.01 lb. per ton, the net earnings being $567,562, out of which $300,000 was paid in dividends.

When organized, the Copper Range Company had $1,000,000 set aside for railroad construction, and $250,000 for development of mineral lands. In 1901 a branch was built to the mills on Lake Superior, and contracts were closed, with the Trimountain, Champion and Adventure mines, to transport their output and supplies. Other railroad arrangements were made with the companies owning the Atlantic and Baltic mines.

Mr. John Stanton took hold of the Baltic mine in 1897; it had never previously been organized into a mining company, but desultory work had been carried out by Capt. John Ryan, the father of John E. Ryan, who is now president of the Amalgamated. A shaft, 60 to 70 ft. deep, had been sunk by him, and a good copper lode was disclosed; but the enterprise never developed to successful exploitation. At the end of 1897, shortly after the organization of the new company by Mr. Stanton, good developments were made on a new lode; milling was begun in July, 1899, by the leasing of an idle stamp in the Atlantic mill. In 1902 the Baltic mill was completed; and of the four stamps, three crushed rock from the Baltic, and the fourth, the output of the Champion. In 1902 the Baltic company crushed 275,932 tons, producing 6,285,819 lb. copper, worth $746,276, and making a profit of $182,762. In 1903 the production increased to 10,580,997 lb. copper, worth $1,421,211, and yielding a profit of $481,447.

In January, 1902, the Baltic mine was acquired by consolidation, the Copper Range Company being re-organized as the Copper Range Consolidated Company, to acquire the stock of the two companies. The new company, organized under the laws of New Jersey, had a capital of $28,500,000

THE TRIMOUNTAIN MINE IN COURSE OF EQUIPMENT

in 285,000 shares. In September, 1903, the capital stock was increased to 385,000 shares of the par value of $38,500,000, in order to carry out the acquisition of the Trimountain mine, which at that time was in debt to the extent of $840,000; but this amount had been expended in legitimate development and equipment, the benefit of which was to appear later. The Trimountain company had fallen into difficulty, by declaring dividends prematurely and so becoming hopelessly crippled for further development. After six months' systematic work, the new company was able to prove that the Trimountain was as rich as the Baltic. The Trimountain, Champion and Baltic are all on the same lode.

In 1903 arrangements were made with Mr. John Stanton representing the Wolverine, Mohawk and Atlantic mines to organize a company, to be called the Michigan Smelting Company, sixty per cent of the stock to be taken by the Champion, Trimountain and Baltic companies. The smelter was completed in June, 1904, at a total cost of about $630,000.

The Copper Range Consolidated Copper Company therefore owns 50,000 shares, or one-half the Champion mine, the railroad, the Baltic and Trimountain mines, six-tenths of the Michigan smelter, 9,300 acres of mineral land west of the Champion location, and a frontage of four miles of mill site on Lake Superior. During 1903 the combined output of the various properties amounted to 30,382,146 lb. copper, which brought $4,054,634.

The story of this important organization has been told at some length, because it is characteristic of the enterprise which has developed the whole region. Moreover, the mining activities of the company are certain to gain in importance as the present systematic plans come to fruition. With a territory covering the main copper belt for 1.75 miles on its strike, and for 4 miles on the dip, this company commands an area of workable copper-bearing ground

which can fairly be said to have been only tested by operations up to date. With its railroad, mills and smelter, it is a self-contained enterprise of great magnitude. From my own visits to the Baltic and Champion mines, as well as to the mills and the smelter, I gained the impression of skilful, substantial work, carried out under the direction of men of the highest reputation. I must confess that until I went

THREE WELL-KNOWN COPPER MEN.
A. Paine. John Stanton. F. McM. Stanton

to Houghton, my ideas of the Copper Range were associated chiefly with the pyrotechnics of Mr. Thomas W. Lawson; and it was only by personal contact with men and things on the ground, that the impression of flamboyant finance was gradually displaced by a keen appreciation of a [illegible] business, the magnitude and substantial character of which it required many days of observation to rightly understand.

VII.—Mining Methods. The Quincy.

Every mining region has local terms requiring definition, if they are to be understood by those living elsewhere. Underground in the Lake Superior copper mines, two products are recognized; the valuable output known as 'copper-rock,' and the refuse or 'waste.' The big masses of native metal are known briefly as 'mass'; the smaller pieces constitute 'barrel work,' because usually loaded into barrels; and, finally, there is the run-of-mine, or 'stamp-rock.' Particles of metal, ranging from slime to nuggets, which are extracted by milling, are collectively termed 'mineral'; according to their purity, they are graded in three, four, or five numbers, ranging in percentage of copper from 25 up to 72. The 'mass' and 'barrel work' will average 95 per cent copper.

Mining methods in the Upper Peninsula exhibit noteworthy differences; and, as these variations in underground practice are based upon diversity of conditions, they are as creditable to the technical men who apply them, as they are instructive to the observer from foreign parts. Before venturing to comment or to criticise, it will be well to describe the manner in which the work of actual mining is performed, in four typical instances.

One of the largest, best known and most representative mines in the Lake Superior district is the Quincy, whose tall rock-houses overlook the waterway that serves as the main highway of transport. The Quincy has seen great changes in mining methods; it is only eight years since the miners went to work underground on a 'man engine'; but that ancient abomination is now a dishonored memory, and the old inclines, "crooked as a ram's horn," have been replaced by straight shafts and winding engines of modern design. Capt. Samuel B. Harris, the former manager, and his son, Mr. John L. Harris, the present superintendent,

have made a great many changes, by way of straightening the working shafts, putting in double skip-roads, and systematizing operations generally. It certainly was high time to do something of the kind, for the shafts, as could be seen on the maps, were getting into a tangle. The two new shafts, known as No. 6 and 7, are at right angles to the strike of the lode, but the older openings were quite uncertain in their bearings; so that while the distance between shafts No. 2 and 6 is 1,928 ft. at the surface, they are only 1,581 ft. apart at the 53d level; in the same way No. 4 and 7 are only 860 ft. apart at the surface, but are separated by 1,254 ft. at the 53d level, which corresponds to a vertical depth of 3,480 feet.

The scale of operation tends constantly to increase; thus, while the skips in the old shafts held only two tons of ore and were hoisted at the rate of 500 ft. per minute, now, in the new shafts, skips carrying eight tons are brought to daylight at a speed of 3,000 ft. per minute, with a maximum of 3,500 ft. The reader will appreciate better what this means when told that the most rapid passenger elevators in the tallest buildings in New York—such as the Park Row building—travel at a speed of only 400 ft. per minute; and even at this rate of descent or ascent our country friend finds his heart in his mouth.

The shafts are 6 by 19 ft. in the clear, and the two skips work in balance—that is, one of them goes to the bottom, as the other comes to the surface. There is no pump, the mine making so little water that it can all be hoisted in tanks. The No. 2, 6 and 7 shafts are equipped to handle 1,400 tons each in 16 hours of actual hoisting, the remaining time (exclusive of intervals between shifts) being devoted to the lowering of men, tools and supplies.

The Quincy mine has 61 levels, reaching to a depth of exactly one mile, that is, 5,280 ft. on the dip, or 4,008 ft. vertical. The lode dips 55° at surface, and flattens to 37° in the bottom workings. No. 7 shaft starts at 54° 30′, holds

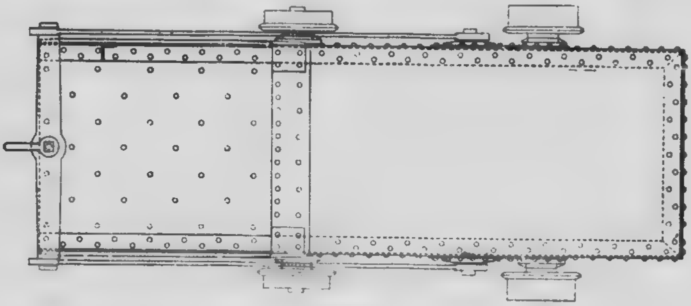
this for a distance of 1,040 ft., and then curves 15′ for 740 ft.; there is a 22′ curve for the next 1,000 ft., and a 30′ curve for 675 ft.; then a 45′ curve for 563 ft., so that at the 58th level this shaft is sloping at 37° and is approximately parallel to the lode, though a few feet underneath it. By carrying the shaft in the foot-wall—about 10 ft. underneath—it becomes safe to stope the lode in its entirety.

The skip weighs 5 tons and carries 8 tons of rock. It is provided with 4.5 in. by 4.5 in. angle-irons one-half inch thick, two at each end of the skip; these are 3 ft. 4 in. long, and extend below the bottom of the skip, so as to serve as guides by passing in contact with the wooden runners which carry the rails. No instance of a skip "jumping the track" is known; quite recently a falling piece of rock struck a car wheel and bent the axle, but the car (or skip) was held between the rails and slid down the shaft, without injury to the track or to anyone near it. Rails weighing 50 lb. per yard are laid in the shaft, while 35-lb. rails are used in the levels. The tramcars used underground carry 3 tons each, and are hauled in trains of three or four by an electric locomotive of 15 h. p., weighing 5,500 lb. All construction is heavy and substantial. In the well-equipped machine and blacksmith shops at the mine, the company makes its own skips, cars and machine-drills. In the blacksmith shop there is a machine for shaping and sharpening the drills. A blank steel bar is instantly forged into a drill ready for work by a pneumatic hammer dropping upon it while being pushed over a die.

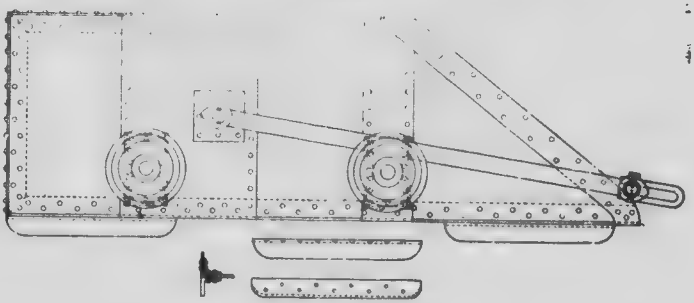
A practice recently started in the Quincy mine is to use a cross bit (sometimes known as a 'rose bit'), for starting a hole, drilling to, say, 3 ft. deep, and then to employ the plain chisel bit in finishing the hole, to the 10 or 12 ft. of total depth. When ready for use, the drills are bunched in lots of a dozen, and are held tightly together by a wrought-iron ring which is kept in place by wooden wedges, on the faces of which the number of the level and the number of

the contract are marked. This arrangement is preferable to the usual rope sling.

Most of the actual mining is done by contract, there being four men (two on each shift) to each contract. The two shifts of 10 hours each are separated by intervals of



Plan



Elevation.

THE QUINCY SKIP.

two hours, which are utilized for getting rid of smoke due to blasting and for ventilating the workings generally.

To prevent over-winding, there is a safety catch, which applies the brakes automatically, unless they are released by the engineer, as soon as the skip arrives within 150 ft. of the surface. When the skip is dumped, the contents fall upon a grizzly, made of fixed cast-iron bars capped by a removable angle-iron, the spaces being 2.5 in. wide. The biggest of the oversize is pushed handily into a low two-wheeled

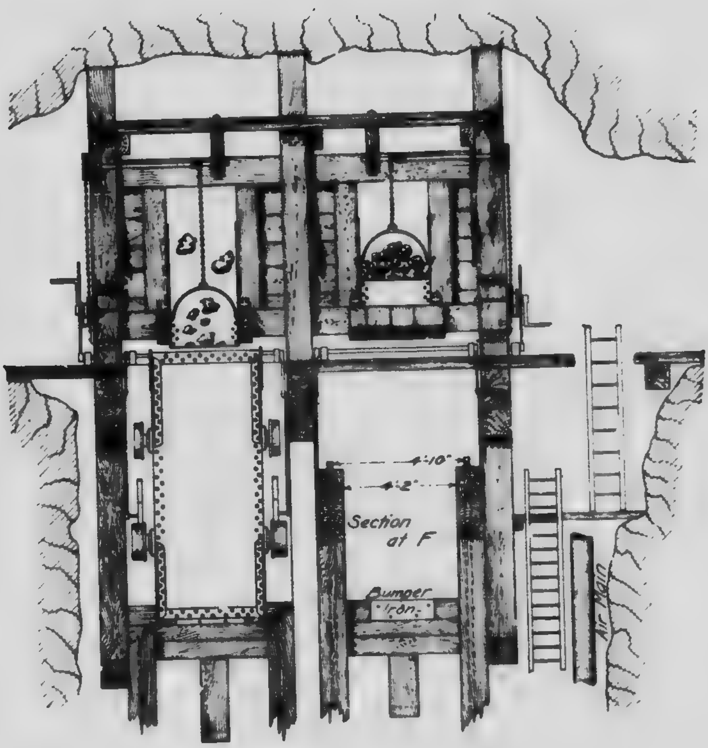
truck, and is then trundled to the rock-breaker; this is an expeditious way of moving the big pieces of rock, and is an advance on the usual manner of pulling them across the floor. The smaller pieces are thrown direct into the crushers. As the grizzlies are laid at a low angle, some of the small stuff rests on the bars; this is hooked to the front and then shoveled into the small crushers. There are three of these in each 'rock-house,' as the shaft-houses are termed. The Blake type of rock-breaker prevails, the biggest with 18 by 24 in. jaws, and the two smaller each 13 by 20 inches. The unwieldy pieces of mass copper go to a drop-hammer weighing 1.5 tons and having a drop of 20 ft., so that the crushing impact is equivalent to 60 foot-tons. Here the rock attached to copper is broken off, the larger fragments going to the crushers, while the remaining metal is lowered into cars for shipment direct to the smelter. Smaller chunks of copper, say, up to the size of a man's hat, are placed under a steam hammer; in each rock-house there is one, the function of which is to loosen the encasing rock so that the copper is rendered clean enough to go forthwith to the smelter.

Methods underground are worthy of detailed description, because they represent a practice which has been evolved from experience. The average stoping width is 8 ft.—ranging from 3 to 20 ft. Shafts are sunk in the foot-wall, and cross-cuts at each station connect them to the main levels. The nature of the hanging wall varies in different parts of the mine. The copper-bearing rock in places is separated from the overlying main plane of lode-fracture, by a narrow band of shaly formation, which is apt to cause trouble; in such places the main drifts are driven well under the hanging, so as to leave a portion of copper rock to support the ground and thereby avoid exposing the shale band, which 'blisters off' or scales, not so much by reason of weathering, as on account of strains brought about by the pressure of the overlying rock-mass, following upon the

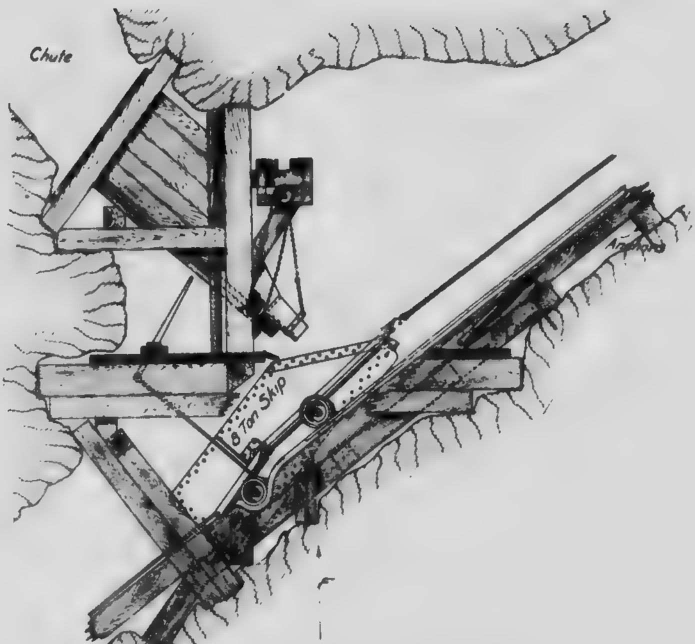
excavation of the extensive upper workings. There are plenty of joints or cross-fractures in the lode; these make the ground heavy in places, but they also facilitate stoping. No cross-veins or feeders of decided character are observable, except a 'spar vein'; this is a vein of calcite, from 3 to 15 ft. wide, which cuts across the lode without dislocating it materially. Mr. John L. Harris, the superintendent, to whom I am indebted for many courtesies, states that displacements in the lode are less frequent the deeper the level, and that several dislocations encountered in the shallow workings—that is, down to 3,000 ft. on the incline—have gradually dwindled to the point of disappearance.

The main difficulty underground arises from the flat dip of the lode. At an angle of 37°, broken rock will not descend freely. Waste rock is built up into walls, which reach from the foot-wall to the hanging, and, in these 'pack walls,' openings are left for the chutes or passes, at intervals of 40 to 50 ft. When the lode is broken by a blast, only the big pieces roll down; the remainder is pulled and hooked down until it lands on a platform or 'sollar' on the foot-wall side of the level, whence it is shoveled into the cars. At each chute or 'mill-hole' the trolley line of the electric tram is protected by a piece of timber, which prevents flying pieces of rock from cutting the wire.

At each station there is an arrangement for the loading of the skip, which merits attention. It is an intelligent device for overcoming the low inclination of the shaft. A winze or 'pocket' is cut in the hanging wall, either in the lode, or in the overlying trap, according to local conditions at the successive levels. This pocket has an inclination which is never less than 40°, and is frequently nearly vertical, so as to allow of a free descent of the broken lode-stuff. Any one of such pockets will hold 500 tons; it will reach down to the next station and terminate close to the shaft, where there is a chute and apron, the latter having a sheet-iron spout, which is lowered when the skip is being



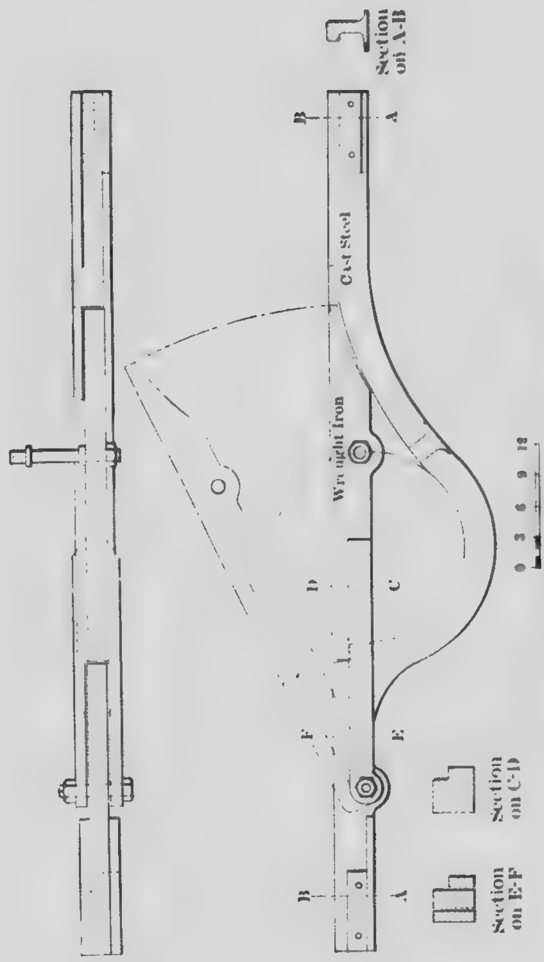
ARRANGEMENT FOR LOADING SKIP.
Front View.



ARRANGEMENT FOR LOADING SKIP
Side View.

loaded. In one instance, at the No. 2 shaft, the same pocket or winze connects three levels, it being so arranged that dumping is practicable at both of the upper two levels —that is, tramcars can be discharged at the 55th level or the 56th, so as to reach the skip at the 57th level.

The loading of the skip to its full capacity is facilitated by the tilting device, shown on the opposite page. About 10 ft. below the floor of the station, a portion of the runner, on which rails are secured, is notched out, so as to receive a device made of semi-steel, as shown in the drawing. This device is equipped with a tongue—about 2.5 ft. long —faced with steel, which takes the place of the rail, and is hinged so that it can be raised by a lever placed at the station. When these tongues are raised, the skip is lowered until its hind wheels drop into the tilting device. Here the skip is firmly held, tilted at an angle of 50°, until loaded from the chute, which is charged from the level above. It is then hoisted, and the tongues (which have rested on the hind wheels) drop back in place automatically, leaving the rails continuous, as before.



DETAIL OF TILTING DEVICE. QUINCY MINE.

VIII.—Atlantic and Wolverine Mines.

The Atlantic mine has achieved an enviable reputation by reason of holding the record in the profitable exploitation of low-grade copper ore. The average output during the last three years has been successively 11.4, 11.095 and 12.76 lb. of refined copper per ton, this being equivalent to 0.57, 0.555 and 0.638 per cent, respectively. It will be interesting to note the conditions and methods which have enabled Mr. Frank McM. Stanton, the manager, and Capt. John Stratton, the mine captain, to attain these remarkable results.

All mining is done by contract. Each contract is usually let to four miners for a block of ground, 90 to 95 ft. long, and reaching nearly up to the next level. The actual height of the stopes will depend upon the nature of the ground—that is, whether or not, for instance, the hanging is heavy, it being customary to leave a floor or arch 12 to 15 ft. thick to support the level overhead, so that the stopes are 70 to 73 ft. in height, as measured from the track of the lower level, each 'lift' being 85 ft. on the lode.

The full size of the lode is broken, 'from trap to trap,' or from foot to hanging wall; the width ranging from 13 to 17 ft., with a steady average of 15 ft. The miners are paid for 15 ft. and must take the full width, whether less or more, as directed by the shift-bosses. It used to be the practice to pay by the cubic fathom; but, owing to the temptation to get an extra width by blasting into poor rock wherever the lode was narrow, it was found more satisfactory to assume 15 as the unit of width, and to multiply this into the height and length when measuring up, before settling with the contractors; but this rule is interpreted fairly by the mine captain, so that no injustice is done to the men in those instances where a width greater than 15 ft. of copper ore is actually broken.

Main drifts are run 8 ft. high and usually the width of the lode. As the driving forms, almost invariably, a part of the whole contract, the width of the drift is left to the judgment of the men, who either break the full size of the ore as they progress, or make a drift 8 ft. wide and 6 ft. high. When the specified distance—90 to 95 ft.—has been advanced, the men come back and extend the 'cutting-out stope' (or, as they express it, "put in the timber ground") to a height of from 16 to 18 ft. above the track. Stulls are put in place, and lagging is laid over them. Then regular stoping commences, and is continued until the contract has been carried out and the ground squared, measured and paid for. Thereupon another stretch of drift is started, and the succession of operations is repeated, as before.

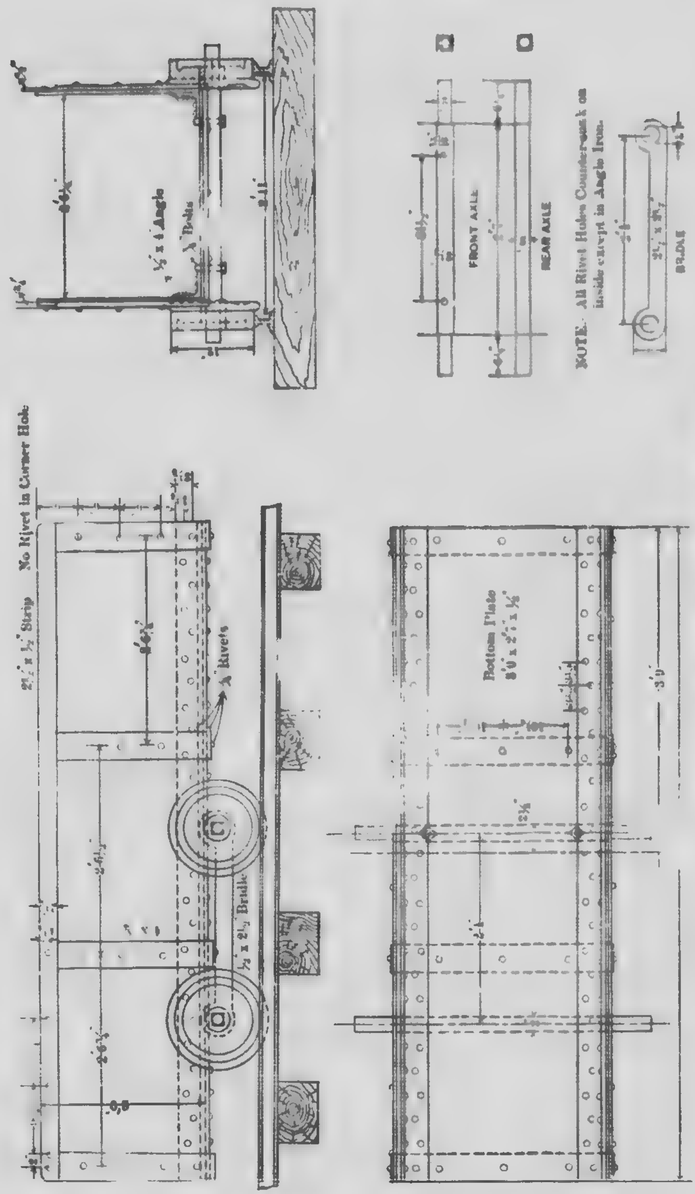
It takes about two months to advance a drift 90 feet—remember that it is carried the full width of the lode—and it requires about three months more to finish the cutting-out stope. Timbering is done by company men as the stopes advance. Stulls over the level are four feet apart, and the lagging is so placed that it can be pulled out between any two timbers whenever it becomes necessary to make a pass for the rock broken overhead. This runs down to a platform or 'sollar,' made of three or four boards laid level with the track, and from this platform the ore is shoveled into the cars. There are no chutes or timbered mill-holes. It is appreciated that the use of them means great wear and tear of timber, so the broken rock is allowed to run down along the foot-wall of the stope, which dips at about 54°, the stulls being arranged in line so as to break the descent as little as possible. The ore broken in the drift is trammed out, but that which comes from the cutting-out stope is left for the miners to stand upon while making the next cut; then this material also is removed pending timbering. When this work is done, and stoping is resumed, the broken lodestuff is allowed to accumulate so as to rest upon the stulls, until the top of the stope—say, 70 ft. above

the track—has been attained; then the lodestuff is drawn away through holes, made by removing the lagging between the stulls at the level.

The lode dips at 54°, and therefore allows a free descent of the rock by gravity; but it is too wide to permit rigging up of the drill on the foot-wall. Scarcely any sorting is done, but as the ore is loaded into the cars underground, an occasional piece of clean trap is picked out; this only amounts to one car in 40 or 50, that is, 2 to 2.5 per cent. At surface some sorting is done in the rock-house, but this also is insignificant, only one car per shift—that is, one in 200 or 220, equivalent to less than 0.5 per cent. This, of course, is an important factor in keeping costs low. In the rock-house one man handles from 90 to 95 tons per shift; there is but little time lost, in picking out pieces of lump copper, as compared to richer mines, for only about 5 barrels, containing 3 tons in all, of metallic copper, are picked out of the total output in the course of an entire month, during which period 30,900 tons of copper ore are hoisted.

Contractors pay for candles, fuse, caps, powder and steel, as consumed. The usual price for stoping is $7.50 to $8.50 per fathom cube, with a fixed width of 15 ft. Drifts—6 ft. high and 8 ft. wide—are worth $6.50 to $8.50 per running foot; but this method of measurement is only adopted when no stoping is included in the contract. In drifts the drill-holes average from 5 to 6 ft. deep, and in stopes 7 to 8 ft. When stoping, 5 holes per shift of 10 hours is considered fair work, this representing the breaking of about 75 to 80 cubic fathoms per month. In drifts, 6 to 7 holes per shift is pretty good; this, at the rate of 40 to 45 ft. per month, the full width of the hole, is equivalent to 16 to 20 cubic fathoms. Twelve cubic feet of rock in place represent one ton.

Timbers vary from 16 to 30 in. diam., averaging about two feet. Two men make the round of the workings to drill 'block holes,' so as to break up masses of rock too big for



TRAM-CAR USED IN ATLANTIC MINE.

handling. The removal of waste is also facilitated by the design of the cars, an important factor in the attainment of low costs. As the accompanying drawing will illustrate, the cars are 8 ft. long, 2 ft. high, and 28 in. wide, inside. Each requires two men, and carries 1.7 tons. The bottom of the car stands only 8 in. above the track, so that shoveling is easy; both ends are open, and the wheel-base is so proportioned to the overhang that the car can be tipped easily at either end, and the sloping surface of the bottom can readily be utilized as a skid for sliding heavy rocks into the body of the car. The trammers pile up the big pieces at each end so as to make a rough sort of retaining wall, and then shovel the small stuff inside. It used to be the practice to fill a closed car from a platform or sollar 28 in. above the track, as is done in the majority of metal mines; but since most of the ore "breaks big," the trammers cannot control the large pieces without great loss of time and the smashing of the cars by the ill-regulated descent of awkward chunks. Two car-loads fill a skip; the latter rests on the track while being charged, but it is kept in place by a gate, a heavy wooden framework hinged to a cross-timber along the hanging wall of the shaft, and lowered into place under the skip by means of a ⅝-in. wire rope, running over a block operated by a lever at the station.

The output of the mine ranges from 1,300 to 1,400 tons of stamp-rock per 24 hours, while sinking of one shaft is going on. This production is due to the labors of 338 men underground, aided by 37 machine drills. The distribution includes:

148 men on the drills; 2 men per drill per shift.

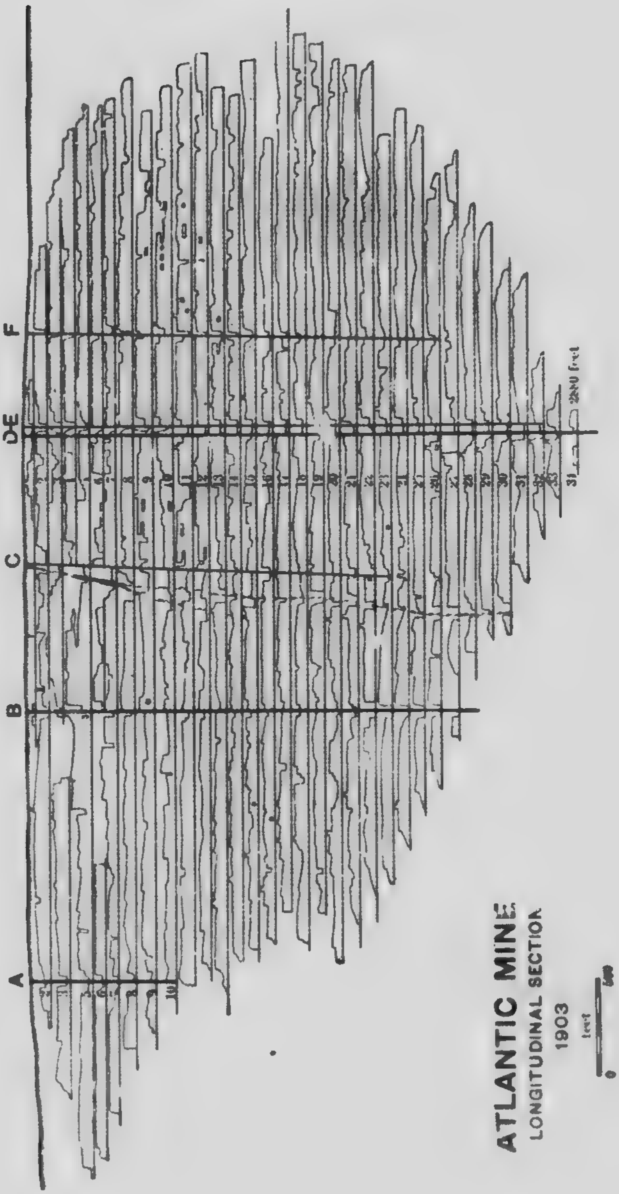
156 trammers, timbermen and helpers.

5 shift-bosses and 2 trammer-bosses.

2 men drilling block holes and 2 repairing skipway, etc.

6 timbermen and 6 helpers.

The care of the shaft, skipway, pumps and actual sinking of one shaft is included. Two boys sprinkle the shaft-


A
B
C
DE
F
ATLANTIC MINE
LONGITUDINAL SECTION
1903

timbers and the drift-timbers with water for a distance of 50 ft. each way from the shafts, in order to prevent 'dry rot,' a fungoid growth which destroys the timber wherever there is either not enough water to keep it wet or where the air is too dry. Formerly the timbers between the 9th and 12th levels used to decay in a year or 18 months; now, by reason of the sprinkling, they last for five or six years.

The low working cost at the Atlantic is due to the comparative uniformity of the lode, bringing sorting down to a minimum; it is also due to the continuity and length of the orebody. This is indicated, better than in words, by the accompanying longitudinal section of the mine. Mine managers in other regions will appreciate the eloquent testimony afforded by the stope-map of the Atlantic. Furthermore, the copper rock is a comparatively soft amygdaloid, easy to drill in the mine, and easy to stamp in the mill. The width—15 ft.—is conducive to expeditious stoping, and the dip—54°—facilitates transfer from the stope to the car. Beyond these favorable factors, and equal in importance to any of them, is one which is to be credited not to nature but to man, and that is sound business management, counting the cents no less than the dollars, and directing operations with an excellence of judgment worthy of the best traditions of the mining industry.

The Wolverine mine is one of the most successful enterprises in the Lake copper district, and for this reason the methods employed underground invite investigation. In general, the system in vogue resembles that which we have seen at the Atlantic, with modifications due to greater richness of lode, a greater width of stoping, and a flatter dip.

When opening a new level, a stope-drift is let on contract, a breast 25 ft. high being carried forward at the full width of the lode, about 12 ft. If stoping is not included in the contract, the drift is made 6 ft. high and 6 ft. wide, the price averaging $5.50 per running foot. Stoping is paid for at an

average price of \$8.50 per cubic fathom of 216 cu. ft.; in the case of a stope-drift the miners receive \$5.50 for the size of a drift, the remainder of the excavation being paid for on a stoping basis.

The lode is remarkably regular in width, and, as a matter of fact, there are no stopes less than 12 ft., except in one place on the West vein; on the other hand, the maximum rarely reaches 20 ft. It has been found, by actual computation from the area of ground excavated and from the tonnage received at the mill, that the average width of rock extracted throughout the mine is 12 ft. I must explain this matter carefully because it is an important factor in the contract system, in the application of which there is an assumed unit of width—which is this 12 ft. The men are paid by the cubic fathom, but in every case the unit of width is the same, even though the stopes should exhibit local divergence from this average. An example will make this clear: If the ground broken by four men measures 20 ft. long by 19 ft. high, then the width is put down as 12 ft., making 4,560 cu. ft., which, divided by 216, is equivalent to 21.1 cubic fathoms, or, at \$8 per fathom, \$168.80. In every contract the width is put down at 12. This practically amounts to payment by square fathom for the full size of a uniform width of lode; and on this basis the price would be twice as much per square fathom as it is now per cubic fathom, the width being 12 ft. in both cases. In the above example 20 multiplied by 19 would equal 380 sq. ft., which, divided by 36, would give 10.55 square fathoms; and this at \$16 per fathom would make the same total, namely, \$168.80. This curious practice is described in detail because it puzzled me a good deal; and it affords an example of empiricism without theory, or, to put it kindlier, of method developed from experience, and adapted to particular conditions.

In order to meet extreme variations from the assumed uniformity, fair treatment of the miners is required, and

they receive it at t[illegible] experienced 'captains.' This is as true at the [illegible] at the Atlantic. If the lode is unusually wide, [illegible] or 20 ft., and the men have fallen short of earning an average wage, the captain "turns in a fathom or two," so as to make it right.

To return to the actual mining: When the drift has been extended to the boundary or to the end of the orebody, a 'stope and raise' is started to reach the level overhead so as to establish ventilation, and make a point of departure from which the stopes are extended backward toward the nearest shaft. The 'stope and raise' is let for a length of 75 ft.; and when it is finished, regular stoping or 'lift and stope' is given out in blocks of 60 to 80 ft. long, this being about the amount of ground covered by a party of four men working for a period of three months. 'Stope and raise' is worth \$7 to \$8 per fathom; once in a while the men are allowed as much as \$9 per fm. in unusually hard ground, but no contract has ever been let at that figure, the extra amount being a special concession made simply as a matter of fair dealing. Plain stoping averages \$7 per fm. Contracts are given to four men with one drill, two men per shift. If only two men are in the contract, the price is \$6.50, because they work on day shift only. The men are paid individually, the subdivision of the total amount earned being done by the company. This prevents subcontracting. Part payment is made every month, but the final settlement is not effected until the contract is finished and the ground squared; the men then get the balance due them. The sinking of shafts is also done on contract, at an average of \$16 per ft., for a shaft 8 ft. by 17 ft. in the clear. The contractors pay for all supplies and steel. A deduction of \$4 per month is made for steel consumed; the drills are weighed at intervals of three months. If two men only are joined in a contract, they pay \$2 per month for their steel. This is for wastage. If any drills are lost, the men pay at the rate of 25 cents per pound.

There is no timbering whatever to be seen either in stopes or drifts. The lode dips at an angle of 40°, and the ground stands splendidly. Even the shafts are not lined, the only timbers being the dividing posts between the skipway and the ladders. The rock does not 'blister' or scale off. A staging of plank on light spreaders is the only wood to be seen in the stopes. When the width removed is unusually great, a stull or two is employed to hold up the broken rock so that the men can rig up their drill in order to reach the hanging; but this is uncommon. Usually the dip and the width of the lode jointly afford conditions permitting the drill to be set up on the foot-wall. This matter of dip is important in several ways; while by being rather flat it facilitates the preparation for drilling, it is, on the other hand, not too flat to prevent the descent of the broken rock. The latter runs fairly well, despite the uneven surface of the foot-wall. Big pieces of rock roll automatically, and it is only the fine stuff that has to be scraped down, which is done whenever a stope is cleaned up on its exhaustion. There are no timbered chutes or 'mill-holes'; as Capt. William Pollard said to me: "The men just put down a board or two, and make a sollar at the level." From this extemporized platform the trammers shovel the ore into the cars. The latter resemble those at the Atlantic; they are 7 ft. long, 2 ft. 6 in. wide, and 2 ft. 2 in. high, with 12-in. wheels and a 22-in. wheel-base, so that they swing around easily. The track is of 3-ft. gauge and the bottom of the car is only 8 in. above it.

The back of the car is closed, but the front is open: the latter has an overhang of 3 ft. 4 in., and when big rocks are handled the front of the car is depressed, so that the bottom of it can be used as a skid. The larger pieces are placed at the front end, making a rough wall, while the smaller stuff is thrown behind. The overhang is less in front than behind, but this is adjusted by the lesser weight at the back of the car. There are three men to each car: one man picks out

occasional pieces of waste while the other two are loading. As soon as two carloads of waste have been accumulated—making one skip-load—they are sent to the surface. The waste from cross-cuts and other barren exploratory workings is dumped into old stopes and is not hoisted.

The lode is a comparatively soft amygdaloid, and does not contain much lump copper; what there is of it is picked out at the rock-house, in amounts varying from 10 to 20 tons per month. At the mill another 10 or 15 tons is sorted out before the ore goes under the stamp. Last year a total of 328,000 tons of ore was hoisted and only 14,000 tons of waste was picked out, this being equivalent to about 4 per cent only of the full width of lode stoped in the mine. The output for the year ending June 30, 1904, averaged 29.61 lb. refined copper per ton of ore, equivalent to 1.48 per cent. The costs, including construction, amounted to $635,185.18, equal to 6.869c. per lb. refined copper; the profit was $557,240.34; consequently the profit was in the proportion of 87.72 per cent. Those who are familiar with copper mining will appreciate the unusually favorable character of the conditions prevailing in the Wolverine mine; if the lode had a dip of 1° more it would be as perfect a proposition as a miner could desire; if the dip were 5° more, stulls would be required for the miners to stand upon; and if 5° less, it would be too flat for the free descent of the broken ore. So it is evident that the conditions are nearly ideal.

IX.—The Baltic. Mining Methods Reviewed.

The main feature of underground work in the Baltic mine is the substitution of rock-walls in place of timbering. Formerly the Atlantic method was employed; long stulls were laid across the top of the drifts, and the drillers rigged their machines on the broken rock until the block of ground had been stoped away to the next level or near it; the lode-stuff was sent straight to the mill, the porportion of waste picked out in the rock-house being about 20 per cent. There was no sorting whatever underground. Such methods might answer with a lode of regular width and fairly uniform mineralization, but the copper-bearing channel of the Baltic is distinctly irregular. In mining, it was the custom to extend the stope upward on the dip, and of the same width as the showing at the level; in consequence, bulges of copper ore were often missed; the rock broken within the narrow limits of this method had all to be sent to the mills, just as it came, and it was therefore low grade.

All this has been changed during the last four years, in accordance with the progressive spirit of Mr. John Stanton, the president, a man to whom the mining industry of the Keweenaw peninsula owes an obligation which the people of the district are always glad to acknowledge. He has been well supported by his son, Mr. Frank McM. Stanton, who is agent of the Baltic mine. The management of this enterprise has brought the experience of the iron regions to bear upon the problem outlined above, introducing modifications suited to the local conditions. I am indebted to Mr. F. W. Denton, the superintendent, for assistance in obtaining a clear understanding of the underground work and for many other courtesies.

Levels are not extended as narrow drifts; on the contrary, each drift is really a drift-stope 8 ft. high and the full

size of the lode-channel, *no matter how wide* it may be; the minimum being 10 ft. and from that to a maximum of 60 ft. The average width of lode-matter sent to the mill is, by approximate computation, 25 ft.; the stopes themselves are slightly wider. When the drift-stope is two or three hundred feet long, work is stopped; all the copper rock is trammed out of the drift along a temporary track, only the larger pieces of waste remaining. Next, a cutting-out stope is started near the shaft, leaving a pillar 25 ft. long. A slice of 7 or 8 ft. is taken out for a length of 100 ft., the position of the permanent car-track is chosen, and large pieces of waste are placed alongside, so as to form the beginning of a wall. As further material is broken down, the larger fragments of waste are put to one side for wall-building, and the small stuff is thrown behind them. Then dry walls, 8 ft. high, are built up; they are four feet thick at the base, and taper to two or three feet at the top, that is, 8 ft. above the floor of the level. Eight feet of clear space is left between the walls for the main working level. At intervals of 60 ft., openings are left for chutes. The next operation is to bring in the 'wall-pieces,' timbers 14 ft long, not less than 14 in. and not more than 20 in. at the small end. Then lengths of hemlock plank, 2 in. thick, are laid along the outer edge of the walls (that is, on the side nearest the level), and the 'wall-pieces' are lifted upon the top of these so as to stretch across the level at intervals of 5 ft., center to center. These timbers are lagged over, and the chutes are built with apron and lip, as shown in the accompanying photograph. A piece of steel plate is spiked to the chute and guides the ore to the lip, the latter being hinged so that it can be raised or lowered by a lever consisting of a hard-wood pole about 16 ft. long.

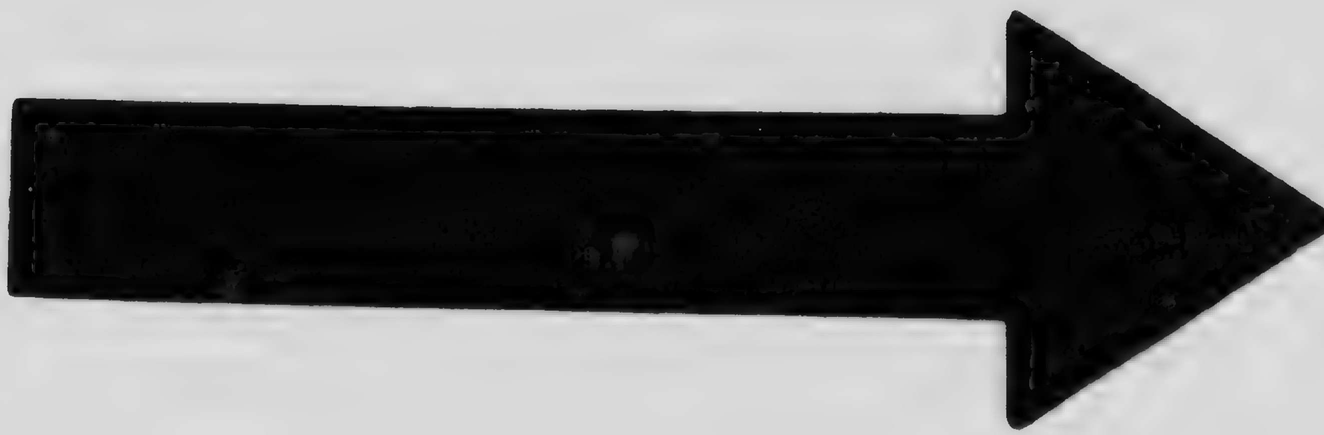
All is now ready for stoping. The first stope is blasted with particular care, so as not to knock out any of the wall-pieces. As the lode is broken down in the course of stoping, the rock accumulates in the wake of the machine

PACK-WALLS IN BALTIC MINE.

drill, forming piles 15 or 20 ft. high. The pickers follow close behind and throw the copper ore into the chutes, and the waste into the fill. Small steel cars, holding about one ton, are provided for the use of the pickers in the stopes when, for any reason, the chutes are not directly accessible. Such cars are used not only for conveying the copper ore to the chutes, but also for spreading the waste; they are made to run on a broad-gauge track, and have a swinging box to permit side-dumping. This work of handling the broken rock in the stopes is being constantly modified. The tendency now is to put the chutes further apart, and to use the small stope-cars more. When the stope gets near the next level overhead, which has been already worked out, it is caved. If the waste picked out is not sufficient for filling the stope, filling material is blasted from the walls, or raises are put in, and old filling is run down from above. Of course, it would be advisable to begin stoping at the boundary and work backward, caving the ground in retreat; but it is claimed that it takes too long to open up the mine in this way, and that there would be no place for the big pieces of waste broken in the drift-stope.

Formerly it was the custom in this mine to use a large amount of timber in the form of cribbing to line the mill-holes, with a view to keeping them open as they are carried upward through the filling; although this practice did not involve anything like the amount of timber required by ordinary methods, nevertheless a great deal of material was thus used. Mr. Denton employs standard railroad ties for lining that portion of the mill-hole near the outlet, with round cribbing higher up. But even better than this, is a more recent modification, now in course of trial, whereby all cribbing is discarded; the mill-holes themselves being built entirely of rock, and circular in shape. As far as I could see the rock is hard enough for the purpose, the wear appeared to be slight, and the idea ought to prove practicable.

A STOPE IN THE BALTIC MINE.



MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

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6.3

The obvious advantage of this system of 'pack walls' and rock-ribbed mill-holes is the small amount of material required to be brought into the mine; in this respect the filling system as used in the Baltic resembles the caving method of the iron regions; and both of them are in strong contrast to the elaborate timbering-methods of most precious-metal mines. Not only is there a minimum of timber, boards, spikes, and such supplies as are brought into the mine, but there is also scarcely any waste sent out, so that the shaft is kept free for hoisting copper ore, which, after all, is the main purpose for which the shaft is sunk. Little waste is picked out in the rock-house; only 6 to 7 per cent of the material hoisted was refuse at the time of my visit, and this came from shafts then in course of sinking. From the stopes, no waste whatever is taken; from the drifts, 1 to 2 per cent only. Apart, however, from the manifest advantages just emphasized, there is another feature—even more important—in that the ore can be extracted more completely, the full width of the lode being explored as stoping proceeds, and the floor-pillars, where rich, extracted by caving. Certainly there is some copper left in the refuse; that is granted, but as against this loss is the copper left untouched in those mines in which the stopes hug the 'walls' and where extraction is confined to a uniform width of a supposedly regular lode. In going through the workings of the Baltic, one can see that the lode bulges and narrows at frequent intervals; it is apparent that the copper extends outward from the axial line of the lode with an irregularity that disregards all attempts to make boundaries by fixing attention upon any persistent planes of fracture.

The lode has a dip of 70° and permits of the full aid of gravity. Cars carry from 2.35 to 2.5 tons each, the lower figure being treated as a minimum. Two men load a car and push it to the shaft. Electric traction is not considered practicable, by reason of the variable tonnage from any one part of the mine. The ore is trammed direct into

the skips, from cross-cuts in the foot-wall that unite the shaft with the levels, the car being dumped while held in a cradle of simple construction.

Work is done mainly by day's pay, the irregularity of the lode interfering with the adoption of the contract system, except for shaft-sinking and some drifting. Miners average $60 per month—26 shifts of 10 hours—or $2.33 per shift. Trammers average $54 per month, or $2.08 per shift. Board is about $18 per month. As a result of method and management, the working costs are low: in 1902, $1.822 per ton of ore stamped; in 1903, $1.607 per ton. This includes all operating expenses on the spot and taxes; it excludes smelting, and marketing of the copper, and New York office expenses, all of which together would come to about 1.3 cents per lb. of refined copper. Measured in this way, the working cost was 7.96c. in 1902, and 7.5c. in 1903; add 1.3c. and you have the total cost per lb. of refined copper. The rock stamped yielded 22.84 lb. refined copper per ton in 1902, and 21.58 lb. in 1903.

The total cost, to be compared with timbering as conducted in other mines, amounted, respectively to 8.67 and 7.97c. per ton during the two years quoted. Details are:

Description.	Cost per ton of rock stamped. 1902. *Cents.*	1903 *Cents.*
Timbermen	6.	4.1
Stope filling, extra waste blasted especially for this purpose	Not segregated.	0.35
Wall building	1.4	1.62
Timber, inclusive of shafts and levels	1.27	1.90
Total	8.67	7.97

It is difficult to separate trammers from pickers, because the former are expected to pick out waste whenever possible. The labor of tramming cost 21.5c. and 17.4c. respectively during 1902 and 1903, while picking labor amounted to 11.5 and 13.8, respectively. Further figures of interest follow; they are arranged with reference to com-

paring them with similar costs under different systems of mining elsewhere:

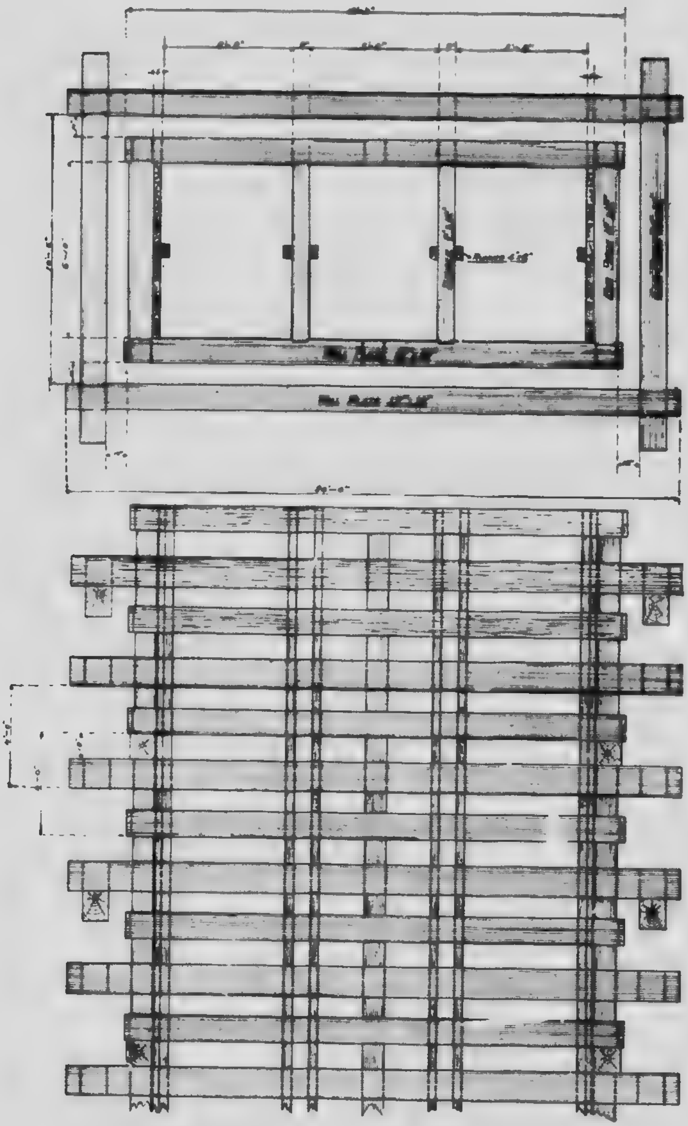
	1902. Cents.	1903. Cents.
Mining, including miners and explosives only	43.20	35.80
Tramming labor, picking labor, timbering labor and supplies	41.67	39.17
Rock-house	9.85	9.08
Hoisting	10 70	5.70
Compressor and air drills (labor, fuel and supplies, repairing machines and sharpening)	9.80	6.70
Surface expense	3.30	1.10
General expense	5.90	4.50
All other expenses at the mine [21]	10.00	8.20
Milling and transportation to mill	38.59	43.70
Taxes	9.30	6.80
Total costs per ton, being the running expense at the mine	$1.8231	$1.6075
Tons stamped	275,175	490,237

The foregoing descriptions of the mining methods employed in the Quincy, Atlantic, Wolverine and Baltic mines afford a good idea of current practice in the Lake Superior copper region. It is true that data covering the methods used in the Calumet & Hecla and Tamarack, would render my account much more complete; but, owing to the fact that the companies operating these two big mines refuse admittance to visiting engineers, there was no opportunity for extending my observations to the deepest workings in the district. However, by courtesy of Mr. W. E. Parnall, the superintendent of the Tamarack, I am enabled to add a drawing illustrating the manner in which Tamarack No. 2 shaft is being re-timbered. (See page 92.) The original set of timbers is supported by a new outer set, which can take the pressure of the ground without twisting the timbers of the working shaft. There is a 10-in. space between the two sets, a bearer from every fourth outer set serving to support the inside timbering. The end-pieces of the outer set are anchored into the enclosing rock. The timbering of the

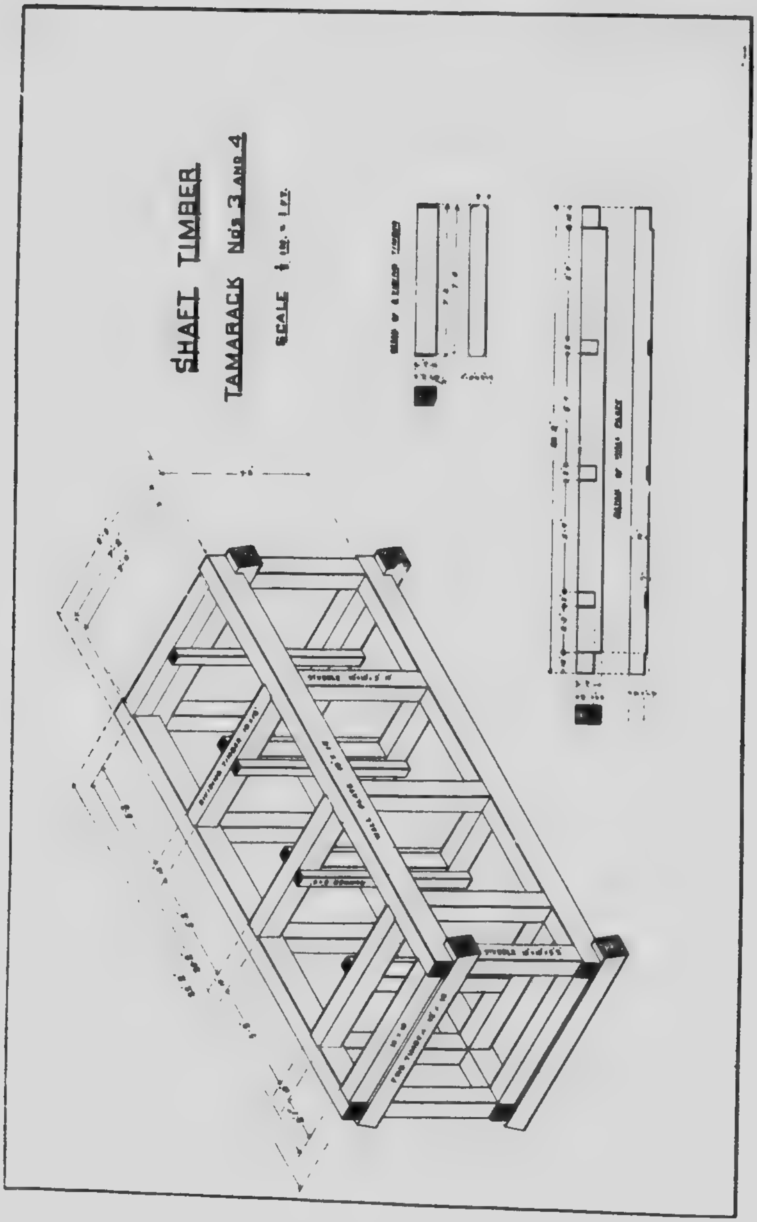
[21] Made up of captains' and shift-bosses' salaries, track-laying, pumping, lighting underground, and various supplies not included in other items.

outer set is under the inner, so that the former can become deformed without interfering with the protection given to the working shaft. Occasional 'studdles' are placed opposite the dividing pieces. A thickness of rock equal to three feet was removed all around the old shaft, in order to permit of this re-timbering, this excavation being equivalent to the rock removed in sinking the old shaft. No. 2 shaft is 4,320 ft. deep. Until the end of 1903, No. 5 shaft, with a depth of 4,938 ft., was the most profound metal-mine opening in the world; but the resumption of sinking in No. 3 has carried that shaft to a depth—up to date—of 5,027 ft. The Red Jacket shaft of the Calumet & Hecla is 4,890 ft. in vertical depth; it cut the lode at the 51st level, and is used only for working ground below the 57th level. The levels are 60 ft. apart, vertically, on a lode with a 38° dip; but stations are cut only for every three lifts, or 180 ft. apart. The product of the stopes is lowered in cars, which travel along an incline connecting three levels; the loaded car stands upon a platform which descends, and in its descent pulls up the empty car. On the level, the cars are trammed to the vertical shaft, and discharge into a pocket which holds just the amount—three cars—required for a skip-load.

Reverting to the general methods of mining, it can be said that the Atlantic lode is of unusual regularity, both as regards width and metal content; the copper appears to be fairly well confined within recognized boundaries; it is disseminated more uniformly than usual, and there is no mass copper to hinder—while enriching—the rapid extraction; the lode favors cheap stoping, by reason of a convenient dip and the occurrence of plentiful cross-fractures. Therefore, on the whole, conditions, as controlled by the width, breaking and composition of the copper-bearing rock, favor the carrying out of the contract system, the elimination of sorting, and rapidity of extraction. This is also true of the Wolverine. The criticism has been made



RE-TIMBERING No. 3, SHAFT, TAMARACK.


SHAFT TIMBER
TAMARACK No's 3 AND 4
SCALE

that the Atlantic method left a large amount of ground under the successive levels; but, having regard to the poorness of the rock and the consequent small quantity of copper buried in such floor-pillars, it appears that the cost of the extra timbering, required to extract this additional 10 or 15 ft. of dangerous ground, would exceed the value of e copper secured.

n the Baltic method no such pillars are left, and the ex-.loration of the lode is carried beyond the apparent walls into the outer country, wherever the copper is found to extend. The bulges, and other irregularities of copper distribution which characterize the Baltic lode, render the adoption of the Atlantic method inadvisable. In fact, the adaptation of method to conditions fulfils the essence of practical mining. In the adjoining property, the Champion, a different system has obtained. An arch 8 ft. thick is left above each main level, mill-holes being cut at intervals of 25 to 30 ft.; the stopes are started above this arch, the miners standing upon the rock, as they break it, until the next level overhead is reached; no floor-pillar is left, because this is rendered unnecessary by the roof-arch. This method is being abandoned, for several rea[illegible]. When the broken stuff is withdrawn from the stop[illegible]ging is apt to break and mix with the mill-ro[illegible]ver, the arches left behind are likely to prove inadequate for the support of the weight of superincumbent ground when the mine becomes deep, and their collapse might induce a creep fatal to the pillars protecting the shaft itself.

In one respect the system of stoping in vogue is open to criticism. That part of the lode which it is profitable to extract, occurs usually in a body of unusual length and persistence, requiring long levels and deep shafts. Frequently the beds of amygdaloid are stoped the full length of the company's property, from boundary to boundary. Nevertheless, the extraction proceeds from the shaft outward, instead of the reverse. By driving the main

CHAMPION MINE SHAFT E.

levels to the boundary or to the known limit of the body of copper rock, and then stoping backward toward the shaft, the ground could be allowed to cave; the track could be taken up; the interruptions to traffic due to intervening stopes would be avoided; and, at the same time, communication, when established between two levels, at those ends farthest from the shaft, would stimulate ventilation. At the Atlantic it was stated that such a plan would render a level non-productive until its full length had been driven; but, surely, in a mine with thirty working faces, *one* can be spared for a time by increasing the extraction at some other place. Once the drift is completed, the extraction at any single level ought to be more rapid if commenced at the end farthest from the shaft. In the Calumet & Hecla, the drifts are extended from shaft to shaft, stoping being started midway and extended in both directions simultaneously. This represents the same idea. It certainly is worth while for the mine managers, especially in young mines which promise to extend to a depth of a mile, and for a distance of as much as two miles, to ponder over this problem, the proper solution of which in each case must play so important a part in the economics of mining.

MASS FOUND IN AN' IENT WORKINGS

X.—Mass Copper.

It is believed by many people usually well informed, that in the mines of the Lake Superior region there are bodies of metallic copper so large that it has been found impracticable to extract them. I remember being told seriously seven years ago that in the Michipicoten district, on the north shore, there were rich copper lodes that were not profitable because the metal occurred in masses so huge that they could not be mined successfully. Similar statements appear frequently in popular accounts of the copper country. But recent investigation of this interesting matter enables me now to dissipate a fallacy which has retained a curiously sustained vitality since the days of Alexander Henry and Douglass Houghton.

The white men who first crossed the lake and penetrated the forests of the peninsula, found evidence of earlier attempts to extract the copper. We know that the Indians worked the metal that outcropped massively at many localities; and there are those who maintain that this was also done by an earlier race of higher capacities long since vanished. Testimony to their effort is shown by the battered fragments of copper dug out of old abandoned workings. Such is the one illustrated on the preceding page; this weighed three tons, and was taken from a pit 16.5 ft. deep at McCargo Cove, on Isle Royale; it exhibits the marks of stone hammers or hatchets. There is good reason to suppose that the Indians built fires around the masses of copper which were too large to be removed; and that after removing the adhering rock, loosened through the effect of the heat, they separated portions with their hatchets by pounding the copper into waves, as shown in the illustration, until it was finally forced apart in small fragments. Furthermore, the reports of the early *voyageurs* made mention of the celebrated 'copper rock,' an immense

boulder of metal found on the right bank of the Ontonagon river; it was visited by the first explorers and travelers, who testified that there was nothing like it anywhere in the world. This mass weighed about four tons; it appeared to be out of place, and may have been moved, by the Indians, thus far from the outcrop of the Minesota lode, a distance of two miles only. It was floated down the river on a raft by Julius Eldred in 18[illegible] to the village of Ontonagon, to be seized subsequently by the United States Government and shipped to Washington, where it can now be seen at the Smithsonian Institution. On inquiry at the Smithsonian Institution, I was informed that this Ontonagon boulder, as it now stands in the National Museum, weighs 6,500 pounds. From a pamphlet by Mr. Charles Moore, entitled 'The Ontonagon Copper Bowlder in the U. S. National Museum,' and issued by the Government printing office at Washington in 1897, I extracted the following data. According to Henry R. Schoolcraft, a member of the expedition that endeavored to bring it away, the greatest length of the mass was 3 feet 8 inches, and its greatest width 3 feet 4 inches. He gave a sketch of the locality, which is shown in the frontispiece. The final effort to remove this unwieldy lump of metal is described thus: "It took a week for the party of 21 persons to get the rock up the 50-foot hill near the river; then they cut timbers and made a stout wooden railway track, placed the rock on the car, and moved it with capstan and chains as houses are moved. For four miles and a half, over hills 600 ft. high, through valleys and deep ravines; through thick forests where the path had to be cut; through tangled underbrush, the home of pestiferous mosquitoes, this railway was laid and the copper boulder was transported; and when at last the rock was lowered to the main stream, nature smiled on the labors of the workmen by sending a freshet to carry their heavily-laden boat over the lower rapids and down to the lake."

The Government paid $5,664.98 to Julius Eldred and sons

for their time and expenses in purchasing and removing the boulder. In regard to the agency which moved it from its place in a neighboring lode to the banks of the Ontonagon river, the balance of evidence ascribes it to the Indians; though it is possible that unknown early white adventurers did the work. In referring to this question, Mr. Moore gives the following interesting information:[22]

"During the winter of 1847–48, Mr. Samuel O. Knapp, the agent of the Minesota mine, observed on the present location of that mine a curious depression in the soil, caused, as he conjectured, by the disintegration of a vein. Following up these indications, he came upon a cavern, the home of several porcupines. On clearing out the rubbish, he found many stone hammers; and, at a depth of 18 ft., he came upon a mass of native copper 10 ft. long, 3 ft. wide, and nearly 2 ft. thick. Its weight was more than 6 tons. This mass was found resting upon billets of oak supported by sleepers of the same wood; there were three courses of billets and two courses of sleepers. The wood had lost all its consistency, so that a knife-blade penetrated it as easily as if it had been peat; but the earth packed about the copper gave that a firm support. By means of the cobwork the miners had raised the mass about five feet, or something less than one-quarter of the way to the mouth of the pit. The marks of fire used to detach the copper from the rock, showed that the early miners were acquainted with a process used with effect by their successors. This fragment had been pounded until every projection was broken off, and then had been left, when and for what reason is still unknown. From similar pits on the same location came ten carloads of ancient hammers, one of which weighed 39½ pounds and was fitted with two grooves for a double handle. There were also found a copper gad, a copper chisel with a socket in which were the remains of a copper handle, and fragments of wooden bailing bowls. At the Mesnard mine,

[22] Page 1029. *Report* of U. S. National Museum, 1895.

in 1862, was found an 18-ton boulder that the 'ancient miners' had moved 48 ft. from its original bed."

The large bodies of metallic copper found in the lodes of Lake Superior are known as 'mass.' The mines which first established the fame of this region, such as the Cliff, Phoenix, Central, Minesota, and National, were all characterized by the occurrence of 'mass.' These chunks of copper were found near the surface, and for years they continued to be encountered underground in great quantity. Such mines required but little capital; they needed chiefly the labor of cutting the metal and of hoisting it to daylight. 'Mass mining,' therefore, characterized the early days. Had the Calumet & Hecla, which has always yielded a strictly stamp-mill product, been discovered in the first decade of development, it probably would have been a failure. The discovery of the Calumet conglomerate came when the rudiments of mining had been learned and when the 'mass' mines were approaching exhaustion.

Two-thirds of the output of the Cliff mine was in the form of masses; some of them yielded from 100 to 150 tons, and as late as 1875 one of 40 tons was taken out.[23] These irregular bodies of metal require special mining methods, for it is impossible to drill into them or to use picks in the ordinary way. Professor Blake has described the usual practice in words that I cannot improve: "The miner picks out or excavates a passage or chamber upon one side of the mass, laying it bare as far as possible over its whole surface. It is usually firmly held by its close union with the vein-stuff, or by its irregular projections above, below and at the end. If it cannot be dislodged by levers, the excavation of a chamber is commenced behind the mass, and this excavation is made large enough to receive from 5 to 20 or more kegs of powder. Bags of sand are used for tamping, and the drift is closed up by a barricade of refuse and loose dirt."

[23] W. P. Blake, *Transactions* American Institute Mining Engineers Vol. IV, p. 110.

Reference is made to this method in the description of the effort which was made to extricate the great mass found in the old Minesota mine.

The Minesota mine, in the Ontonagon district, was celebrated for large masses. The largest was found in 1857; its greatest length was 46 ft., its greatest breadth 18.5 ft., and its greatest thickness 8.5 ft. The mean width was 12.5 ft., and the mean thickness 4 ft. Twenty men labored 15 months to remove it from the rock; some of the cuts had a face of 16 sq. ft., and the cutting-up yielded 27 tons of copper chips. The weight was estimated at 500 tons,[24] but I shall have more to say about this directly.

The circumstances of this work are told graphically by Geo. D. Emerson, whose statement is quoted in 'The Mineral Statistics of Michigan' for the year 1880. "They uncovered a series of masses with an eastward inclination for the length of 70 to 80 ft., and going out of sight both above and below. It was at once apparent that they had something very valuable, but they had no conception of the immense thing which a few days' work disclosed. At one convenient point they broke away behind the copper so as to get in a sand blast of five or six kegs of powder. They stripped the mass further, and again fired without result. Again they fired nine kegs of powder, and the mass remained unmoved. Breaking the rock around for a considerable distance, 18 kegs of powder were shot off without effect, and again 22 kegs, and the copper entirely undisturbed at any point. After further clearing, 25 kegs were shot off under the copper, and it was thought with some effect. But a final blast of 30 kegs, or 750 lb., was securely tamped beneath the mass and fired. As soon as the smoke cleared away a mass of copper 45 ft. long and 3 to 5 ft. in thickness, apparently very pure, and which will probably weigh 300 tons, had been shot out and was ready for cutting up. The blast had torn the immense body from its bed without

[24] 'Mineral Statistics of Michigan,' 1880, p. 76.

exhibiting a sign of breaking or bending in any place, so great was its thickness and strength. It was torn off from other masses, which still remain in the solid rock."

They had exploded 110 kegs, or 2,750 lb. powder! One might remark that, had the copper proved less resisting to the violent efforts of these miners, it would not have possessed the value in art and industry which we accord to it. The tenacity of the metal, as recognized by these workers underground, may have hindered its easy partition, but it certainly is one of the qualities for which it commands a price when it reaches the surface. However, the mass, whose removal is told so well in the above quotation, was undoubtedly the largest single body of metallic copper ever mined. Its weight has been variously stated in many reports as having been 500, 530, or 585 tons. Quite recently, however, certain papers covering the business of the Minesota mine were found by Mr. Samuel Brady, the manager of the Michigan mine, which is the successor of the old Minesota, and the data therein contained prove that the celebrated mass weighed 420 tons.[25] These bodies of copper are extremely irregular in thickness; they are ragged in form and straggle through the lode until they nearly connect with other monstrous nuggets. Such was the character of the series of masses encountered in the Bay State mine, now the Phoenix, forty years ago. These aggregated some 600 tons; but they were bodies, none of which singly exceeded 200 tons, connected by strings of metal. Therefore, the fact remains that 420 tons is the largest single mass of native copper recorded in the history of mining.

The practice then was, and still is, to cut the mass with cape chisels having a ¾-in. bit, the successive chips

[25] This information is contained in a letter dated October 3, 1865, addressed by Capt. William Harris, manager of the mine, to the secretary of the company, S. M. Pond.

being about $\frac{1}{8}$ in. thick. The narrow strips obtained from this operation, when made by skillful operators, and in the absence of any flaw or included rock along the course of the chisel, are taken in one cut through the entire 'mass.' The earlier method was to carry the chip about $\frac{1}{8}$ in. thick, as stated, and of equal thickness on both sides; but later this was changed to a more rapid way, the chips thinning to an edge and alternating, as is usual with a cutting made by a chisel of this kind, the process being similar to the driving of a key-way. The narrow strips obtained from this operation are only about half the length of the groove which yielded them, because the metal becomes pressed together and thickened by the blows of the cutters. Certain men made a specialty of this work and became expert, so as to cut a square foot of surface per shift; this meant that one man held the chisel and guided it along the line of cut, while two others struck the chisel alternately with sledge-hammers. The cost averaged \$12 to \$14 per sq. ft. Nowadays, when the cutters are not often needed and special skill is not available, the cost (when done by hand) is greater. At the Michigan mine the pneumatic hammer has been used recently for cutting mass, and with success. Mr. Brady informs me that the actual cost of cutting two masses in this mine, during the current year, was \$3.15 per sq. ft., exclusive of power. The cost of cutting the 420-ton mass, previously described, appears, according to a letter of Capt. William Harris, bearing date of October 3, 1865, to have been \$12 per square foot.

At the Quincy some masses have been found in recent years, but no big ones. Five or six tons is the limit for convenient handling, but, of course, this will depend largely upon the shape of the mass. Larger bodies are cut so as to yield pieces suitable for tramming and hoisting. The time taken in the cutting depends upon the shape; sometimes a narrow neck connects two outlying portions, in which case the division is facilitated. The photograph on

MASS COPPER SHOWING CASTS OF CALCITE CRYSTALS.

the opposite page illustrates the cutting of a mass weighing six tons.

It will be obvious that masses of portable size are less expensive to extract than the very big ones; or, to put it in another way six lumps of 5 tons each and needing no cutting, will yield more profit than one of 30 tons, which may require to be cut into five or six portions. It is said that the great mass of the Minesota mine did not leave much of a margin for profit, for this reason; and it is obvious, from the description already given, that a good deal of vain effort was expended in extricating that elephantine chunk; but the wages of even the 20 men mentioned, who worked 15 months to remove it, would aggregate only $18,000 at the most, and against this there would be the 420 tons of copper; this would yield about 79 per cent refined copper, or 324.17 tons, which, at $400 per ton, net cash on delivery, after deducting cost of transport, conversion and sale, would yield a total of $129,668,[26] so that the mining cost represents only 14 per cent of the value realized. As a matter of fact, the chips obtained in cutting are usually enough to pay for the cost of the operation The 27 tons of chips taken from the Minesota mass were worth, under the conditions and prices of 1857, not less than $8,500; and it is certain that the cost of extracting this particular mass was extraordinary, on account of its size and the difficulty of getting it out of the lode. It can be asserted confidently that no one in the Lake Superior country is afraid to encounter mass copper for fear it should prove unprofitable!

Incidentally, it will be interesting to refer to the occurrence of native silver. The largest piece of pure silver found within the last few years was in the Mass mine, and it weighed 12 lb. This piece formed part of the Michigan

[26] In making this estimate I am guided by the report of the National Mining Company, the neighbor of the Minesota, published in *The Mining Magazine*, December, 1857.

mineral exhibit at St. Louis. In 1873 a small boy, while 'cobbing' or selecting bits of copper rock in the dump of the national mine, at Rockland, broke, from a piece of conglomerate, a lump weighing 16 lb. Capt. J. C. Thomas, now at the Michigan mine, and formerly at the Cliff, states that he has seen pieces of practically pure metal weighing

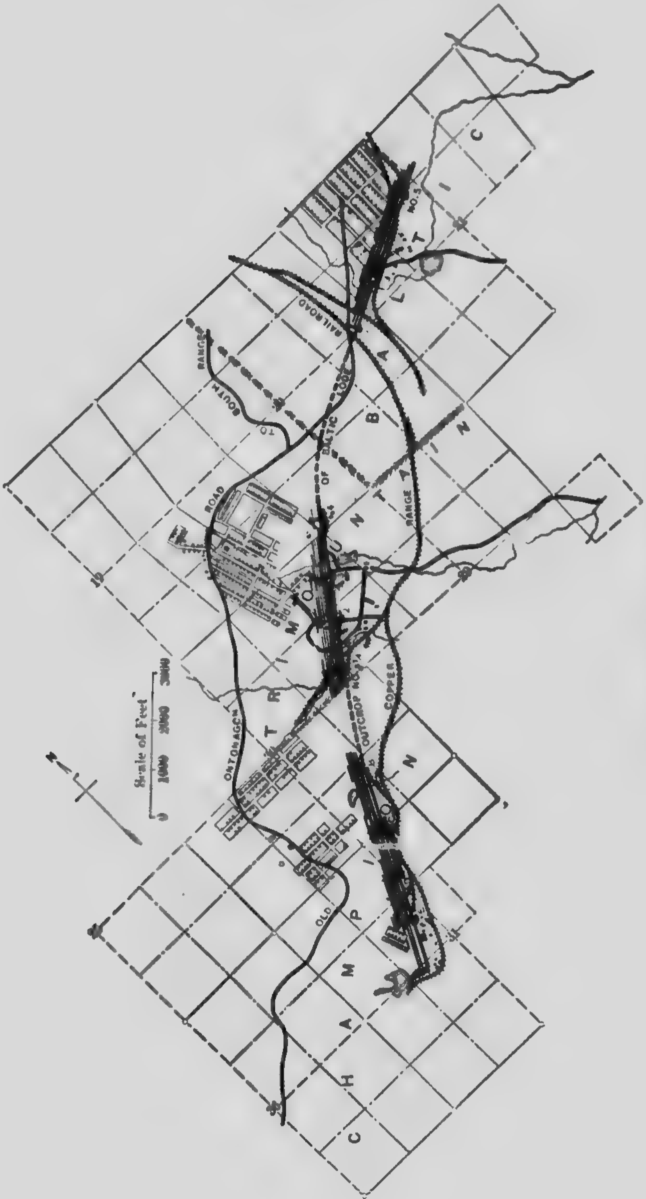
CUTTING A MASS. QUINCY MINE.

from 25 to 30 lb. taken from the Cliff mine, as much as $500 worth being extracted in a single night by the men, who presumably did not report the fact to the office. Many thousand dollars have been taken from the mines of Lake Superior in the form of silver secreted by workmen, not to mention the specimens which now enrich museums all over the world.

XI.—Exploration.

The maps showing the holdings of the different companies in the Lake Superior region, exhibit none of that confusing interpenetration of claims which characterizes the mining districts of the Rocky Mountains. That iniquitous principle represented by "the law of the apex" is not known; acreage replaces apex rights; and simplicity of tenure obviates the interminable litigation which seems to be the necessary baptism of a rich mine in Montana or Colorado.

Any map of the region (as, for instance, that of the companies on the South Range, on the next page) exhibits the checkered squares of the sections into which each township is subdivided. There are 36 sections to a township; the latter is six miles square, so that each section represents 640 acres, further subdivision being made into quarter-sections of 160 acres, and these again into 40-acre tracts. The boundary lines carry mineral rights vertically downward, without restriction of any kind. The ownership of the land near the copper mines has passed out of the hands of the original owner, the Federal Government; it is now held by individuals, where not consolidated into company holdings, there being one exception in the case of the St. Mary's Canal Mineral Land Company, which, by reason of building the great waterway of the Lakes through the Sault Ste. Marie, was given a grant of land, a large portion of which was selected so as to cover that part of the copper belt not already pre-empted. It is on this territory that those discoveries were made which led to the making of the mines on the South Range. Another exceptional landowner is the public school; by State law, every Section 16 was set aside as the property of the public schools, and it is a matter of regret that no Section 16 has as yet proved to be the site of a rich mineral development.



THE COPPER RANGE MINES.

The fact that the extension in depth of the lodes was not properly secured by claims in the direction of dip did not enter into the calculations of the early operators, but now that persistence in depth has been established there is more foresight shown. The Calumet & Hecla Company, for example, undoubtedly made a blunder in failing to secure the 'deep level' of their big discovery, an omission which became the basis for the organization of the Tamarack, whose first shaft went down vertically 2,100 ft. before it cut the Calumet conglomerate. At the present time the Allouez is another example of a 'deep level' enterprise, it having been planned on an estimated dip of 38° to cut the Kearsarge-Wolverine amygdaloid at 1,100 feet.

Bold outcrops of rich ore do not characterize the Lake district, so that the beginnings of a successful mine require more than the ordinary prospector's activity. The Mohawk was found by the uprooting of a tree, caused by the falling of another tree which had been felled by a woodchopper. Mr. John Stanton had obtained an option on the property with a view to prospecting. The chopper brought him a lump of rock showing copper, which adhered to the roots of the tree, and he then arranged for a systematic exploration. Thirteen pits were put down to a depth of 30 to 40 ft., and for lengths of 25 to 45 ft. across the strike of the lode. All save two of these trenches exposed copper ore of good grade, and the evidence thus obtained was held to warrant the sinking of shafts. In this case the drift overlying the true rock was only 12 to 20 ft. thick; but elsewhere in the district such prospecting is rendered expensive by reason of a heavy overburden of drift. On the Globe ground, just south of the Champion, there is as much as 200 ft. of 'wash'; and, in order to determine the position and value of the lode, it was necessary to put down two diamond-drill holes from a point some distance dipward, so as to strike the lode at right angles, and these holes passed through 225 ft. of drift and 600 ft. of rock

before they cut the ore, with results that warranted the expenditure.

A good example of the application of geological knowledge to mining exploration is afforded by the story of the Champion mine. But before this is related, a few introductory remarks are necessary. The trap beds—that is, the layers of diabase forming so large a part of the Keweenaw series—are so nearly alike that identification is ordinarily impracticable, but occasionally some mineralogical characteristic will serve as a guide; thus the foot-wall of the Kearsarge amygdaloid is a bed marked by large feldspars. Dr. L. L. Hubbard, formerly State Geologist, used this fact to determine the position of the Kearsarge amygdaloid, and he proved that it was a safe indicator. It is also proper to state that the officers of the Michigan Geological Survey recognized the foot-wall at the Mohawk as being this same bed, before they knew that any openings had disclosed copper; and they made known this identification at once, although it was a long time before the people of the district would admit the correctness of the correlation. Usually the amygdaloid layers are more susceptible to weathering than the compact trap encasing them, consequently they become covered with drift and soil. The conglomerate beds, on the other hand, resist erosion and form occasional outcrops. It was through one of these that the Champion mine was discovered.

The Champion location covers the southern extension of the Baltic lode; in the Baltic mine there is a conglomerate bed lying 112 ft. to the east—in the foot-wall—of the Baltic copper-bearing amygdaloid; this conglomerate is supposed to be Marvine's No. 3. In his explorations over what is now the Champion company's ground, and over what was then a tract of bush-land belonging to the Canal company, Dr. Hubbard found one solitary outcrop of what he took to be the No. 3 conglomerate just referred to; this outcrop was 50 ft. long—long enough to give a line of strike; he

then stepped off 112 ft. westward and came to a ledge of trap, evidently not what he was seeking; but a few feet beyond there was a depression in the surface marking the course of a stream, in the bed of which he found an amygdaloid. By following the course of this amygdaloid, along another depression between two outcrops of trap, he soon unearthed some copper ore. Then, guided by the strike of the conglomerate, he followed the parallel amygdaloid; he made 13 openings, and found the copper lode in all of them. This was the beginning of the Champion mine, of which the successful geologist just mentioned is now the efficient manager.

While I was at Houghton there was talk of discoveries on Section 15, a tract on which this same Baltic-Champion lode had been found. As I wanted to see what appearance was presented by an infant copper mine of the Lake Superior type, I went to see the discovery, by the courtesy of Messrs. R. E. Pryor, James Blandy and J. P. Edwards. Work was proceeding in an open-cut, recently enlarged from a prospecting trench, at the bottom of which a copper lode was exposed. One foot to 18 in. of soil and gravel formed a surface layer, in which nests of carbonated copper were buried; these were essentially pieces of 'float' copper, so oxidized that the carbonated mass usually contained only a nucleus, as big as a pea, of copper coated with cuprite and buried in malachite and azurite. Under this layer came three or four feet of 'hard pan,' a mass of brecciated rock and gravel well cemented, in which were seen further fragments of copper coated by cuprite and surrounded by carbonates; below this, within the seams in the amygdaloid rock, there were copper stains for a further depth of 8 or 9 ft., although the country itself exhibited no weathering. The open-cut showed a wide lode carrying metallic copper distributed irregularly and to an extent which the eye could not gauge. A succession of trenches indicated the manner in which the lode had been traced.

THE BEGINNING OF A MINE ON THE SOUTH RANGE.

Mr. Edwards told me the story of this young enterprise. At the southern end of the ground, he had found a solitary outcrop of conglomerate; as I saw it, it was a rounded hummock amid the bush, rising three or four feet above the general surface and extending for 40 or 50 ft. He sunk pits in this conglomerate, to determine the line of the strike and to permit him to infer the relative course of the amygdaloid lode he was seeking. Mr. Edwards had made up his mind that this was the No. 3 conglomerate, which is quite prominent at surface north of the Baltic; and, knowing that its normal position was 112 to 115 ft. east of the Baltic amygdaloid, he obtained a line of departure for his prospecting trenches. At 130 ft. he found the lode he was looking for, the greater distance being accountable to the difference in dip, 55° here, as against 73° at the Baltic. Thereupon Messrs. J. P. Edwards, R. C. Pryor and others went to work to secure terms from the owners of the land, which was held in 40, 60 and 95-acre tracts by various individuals. These gave them an option, on condition of $10,000 being raised for exploratory work; and, this being done, a local company was then organized to take over the option and distribute the shares *pro rata* according to the acreage of each participant. Enough treasury stock—50,000 shares—was created to enable working capital to be raised as required for the mining operations; 10,000 of these shares were sold at $1 to meet expenses of prospecting, while the remainder was kept in the treasury for further contingencies. It is intended to proceed with exploration and development. When sufficient work shall have been done and enough copper ore accumulated, arrangements will be made to lease a stamp and to ship the output over the nearest railroad to the mill.

This story has been related to exemplify the manner in which mining enterprises are started in this region. Every district has its own method, dependent entirely upon the nature of the mineral discovery and the amount of capital

required to make a profitable mine. Of course, in the case of these low-grade copper mines, there is an enormous amount of money required for development, for a mill, usually for a railroad, and sometimes for a smelter, before the enterprise is finally placed upon the safe plane of an investment.

In comparing these lodes of native copper with other metalliferous deposits, they are found to present one striking feature—the impossibility of sampling them. To anyone accustomed to precious-metal mining, in which every stage of intelligent enterprise is checked by accurate sampling, the inability to employ this method in the Lake Superior mines presents a subject of peculiar interest. It is obvious that the occurrence of the metal in a native condition, and in sizes ranging between the microscopic and masses weighing many tons, offers an insurmountable obstacle to any sampling method which is based essentially on the doctrine of averages. To sample a vein containing free gold in pockety form has long been given up as a hopeless task, more likely to mislead than to guide; this is practically the problem in the Lake Superior region. No cross-sectional determination of contents by channeling a breast of copper ore will help the appraiser of values, because not only is the distribution of the metal sporadic, but it occurs in a form rendering it impracticable to break a true sample. A moil and a hammer are of no more use than a pocket-knife when it comes to cutting across a lump of tenacious metal, or a concrete of shot copper, and such is the usual composition either of an ordinary amygdaloidal, or of a conglomerate, copper lode.

The sampler and the assay-plan are unknown at Houghton and at Calumet; but other methods are employed. In the first place, experience enables a man to judge the percentage of copper in the rock; such judgment is subject to error, as being at best only a guess, but it serves a useful purpose, especially when applied to different faces of the same lode, each having its own copper habit, that is, a

certain ratio between the lumps and the finer particles. When examining a new discovery or a young mine undergoing early development, an experienced man will separate the 'barrel work' or lumps of metal coming up in a given number of buckets or cars, and in that way he can determine the number of pounds of copper per ton of rock. Of course, he has no way of getting at the fine copper scattered through the rock, and he must decide from the character of the lode how great a part this plays in the actual percentage of metal present. If it appears from a test such as this, that the lode is rich enough to become the basis for a profitable mine, then development is pushed until the enterprise reaches the next stage. This is the accumulation of sufficient copper ore to permit of the leasing of a stamp and the making of a mill-run. There is usually some mill in the district which is idle or has a stamp—out of two or three—which can be leased. The work of one stamp means the crushing of from 500 to 600 tons per day; and the trial may cover a shipment of 1,000 tons, or it may mean steady crushing from a continuous output. In either case, the quality of the average output of the mine is adequately tested, and this may warrant either the leasing of milling facilities for a term of years or the erection of a mill in connection with the mine. The charge for custom milling ranges from 40 to 45 cents per ton.

It was by such methods that most of the mines made their beginning, and it is obvious from this account that the determination of the value of a copper mine requires capital. It takes a gold mine to make a copper mine; but it is fair to add that when the copper mine is once set going in the Lake region, it outlasts several gold mines of the average kind.

XII.—Milling Methods.

The thunder of the ordinary stamp-mill may be likened to the rhythmic crash of the surf; at a distance, especially among mountains encouraging an echo, the muffled roar of many stamps is as the voice of the sea when heard from far inland. But the steam-stamp has no poetry; it is all business. It seemed to me, while in the Lake Superior copper region, that whether a mill contained one stamp or twenty, it was only a single elephantine thump that I heard. Inside also there was not the confusing uproar which accompanies the work of gravity stamps when under cover, but the decisive thuds of one or more heads sending their tons of weight into the bed of ore on the dies. In Gilpin county, Colorado, a mill that crushes 500 tons *per diem* would contain three or four hundred stamps, while a California mill with equal capacity would require about two hundred, and, similarly, a South African plant treating 500 tons would have 100 stamps; therefore, to the visitor from other mining regions, a mill of one stamp appears a lonesome piece of machinery, until it is realized that it crushes a tonnage equal to the output of a whole row of batteries of the ordinary type. The Isle Royale mill, the first one I visited, because it is close to the town of Houghton had only one stamp in operation, yet it crushes 550 tons *per diem*, and the contrast with earlier experiences was vivid.

There is less noise; there is also less vibration; and, by reason of the absence of long belts from shaft to countershaft, there is more room, which is utilized to the extent of employing the feed-floor as a machine shop. At the very beginning of the milling, and thence to the end of the operation, the object of the reduction process is in plain sight. With a gold ore of average grade, one does not see

the metal; it is extracted when still alloyed with mercury as an amalgam, as a concentrate intimately associated with bright sulphides, or as an unseen element in black slime. But in this treatment of copper ore, the metal stands out everywhere—it is picked in big chunks out of the broken stuff running from the bin into the mortar; it is discharged in lumps as big as potatoes from the mortar itself; it is taken as a red gravel from the roughing jigs; it comes in finer grains from the finishing jigs; and as a red mud from the Wilfleys. Throughout the series of operations, the object of all the expenditure of machine power and human labor is plainly visible. Finally, it is collected, not in the relatively insignificant proportion in which gold is obtained, but lavishly, to be loaded into oil-barrels, of 52 gal. capacity; each of these contains 1,500 to 1,800 lb., and when ready for shipment, they are sent on railroad cars, to the smelter.

In the early days, when the Eagle River and Ontonagon mines were the principal producers, that part of the output which went under the stamps was unimportant, the profit being made from 'mass' copper. The early stamp-mills were crude affairs; it was the practice to calcine the rock before stamping in order to facilitate the crushing. The practice obtaining in 1876 was exemplified by the Allouez, where the millstuff went from the stamp to a hydraulic separator, the slime passing to settling boxes and then to convex tables of the Evans type; while the oversize from the separator went to seven double jigs. The Allouez company, in that year, erected a separate mill of 28 Cornish stamps to re-crush the coarse sand, their attention having been called to the loss incurred from insufficient grinding. The stamp screens had $\frac{1}{8}$ in. holes, and the water employed amounted to 47 tons per 24 hours per ton of rock crushed, or 1,556 gal. per min. for two stamps.

In 1855 the cost of stamping at the North American and Copper Falls mills was from $1.65 to $2 per ton; in 1874 the Quincy brought the cost down to $1.08; and, in 1881, with

TRIMOUNTAIN MILL.

the introduction of the Ball stamp, to 72 cents. In 1882 the Atlantic attained a record with 37 cents per ton.

While at the Tamarack mine I saw a train of eleven cars, carrying 440 tons of mine ore, about to start for the mill. This entire trainload of copper ore was insufficient to keep one stamp going for one day. Twenty-five years ago the maximum capacity of a steam stamp was 150 tons of amygdaloid; seven years ago it was 350 tons per stamp; now the new compound stamp has a one-day record of 779 tons, and a two weeks' record of 725 tons per 24 hours of actual running, or a duty of 700 tons per day, including stops. This has been done recently at the Osceola mill on Kearsarge amygdaloid.

To convey the product of this powerful crushing machine, an enormous volume of water is required. The average consumption is 3½ million gallons per head per 24 hours. At the Quincy mill an Allis triple-expansion pumping engine throws 16,000,000 gal., and a Worthington pump 12,000,000; this supply of 28,000,000 gal. is consumed by the eight stamps, of which seven are usually at work. There is an overflow of 3,500,000 gal., or sufficient for another stamp—which includes, of course, the array of jigs and tables that represent the scheme of treatment. In an ordinary stamp-mill the water used averages 3 to 5 gal. per stamp per minute, or about 10 tons of water per ton of ore. In these steam-stamp works, the ratio is 30 tons of water to one ton of ore crushed.

The process consists of coarse crushing—through screen openings of ⅝ inch—followed by successive elimination of the copper by jigs and concentrating tables, aided by the usual classifiers. A small part of the material undergoes re-grinding. It is a process of elimination of a single product—native copper—by gradual concentration, the crude material being to the final product in the ratio of about 60 to 1. A Montana mill treating mixed sulphides would be nearly four times as big.

STEAM-STAMP AS SEEN AT FEEDING FLOOR.

The steam-stamp was invented by Ball, who had built steam-hammers, and saw their availability for crushing ore; the steam-stamp may also be regarded as a gravity stamp of great weight, actuated directly by a steam-engine, the stem becoming the extension of the piston. In the Leavitt design, in which the steam is admitted only at the top of the cylinder, the stamp-shaft, with its attached shoe, on striking the bed of ore, rebounds against the condensing cushion of steam, so that the uneven surface of ore on the die suffices to turn the stamp. But this turning is quite irregular; it is scarcely appreciable for two or three successive drops, and then comes a grand whirl equal to half a revolution. In the Allis and Nordberg stamps, the steam is admitted to the cylinder both at the top and bottom; the steam admitted through the upper ports drives the stamp-shaft down into the bed of ore upon the die, the stamp being immediately raised at the end of the stroke by the admission of steam through the lower ports of the cylinder. By reason of the force with which the shoe is driven into the ore, a mechanical device is required to turn the stamp.

On the whole, while the steam-stamp is an impressive rock-breaker, it is a bad pulverizer and an expensive kind of engine, for it uses 45 to 60 lb. steam per horsepower-hour. Greater economy has been secured by the introduction of the compound system. In the Osceola and Champion mills, the use of compound engines on the stamps has met with excellent results and has enabled the attainment of a maximum crushing capacity—710 tons per head.

The ore contains lump copper, which the stamp of course fails to crush, and only serves to deform; this is extracted by two devices, both of which are described in the notes which follow. These lumps of metal, like potatoes in size, used to be a serious obstacle. Before the automatic discharges were invented, it was necessary to stop three or four times in a shift, and raise the stamp on blocks, while

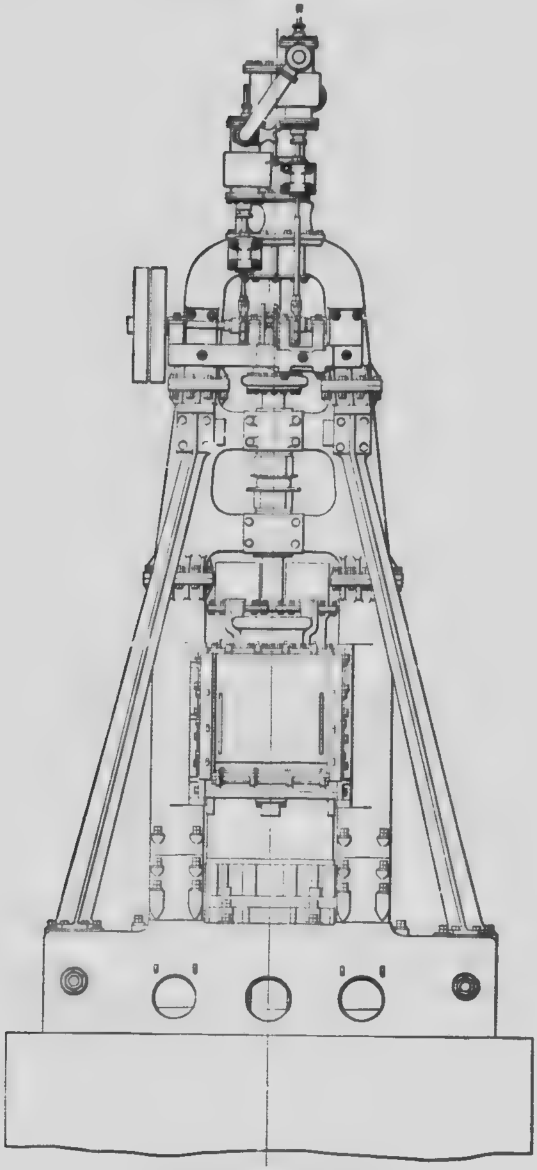
prying out the chunks of metallic copper with picks and crowbars.

A look at the ragged, irregular pieces of copper, with their attached rock-matrix, as they appear before going under the stamp, and the examination of the rounded nuggets as discharged from the mortar, after being pounded under the stamp, will enable one to realize the waste of power and the abrasion of metal which must take place before the milling operations are properly started.

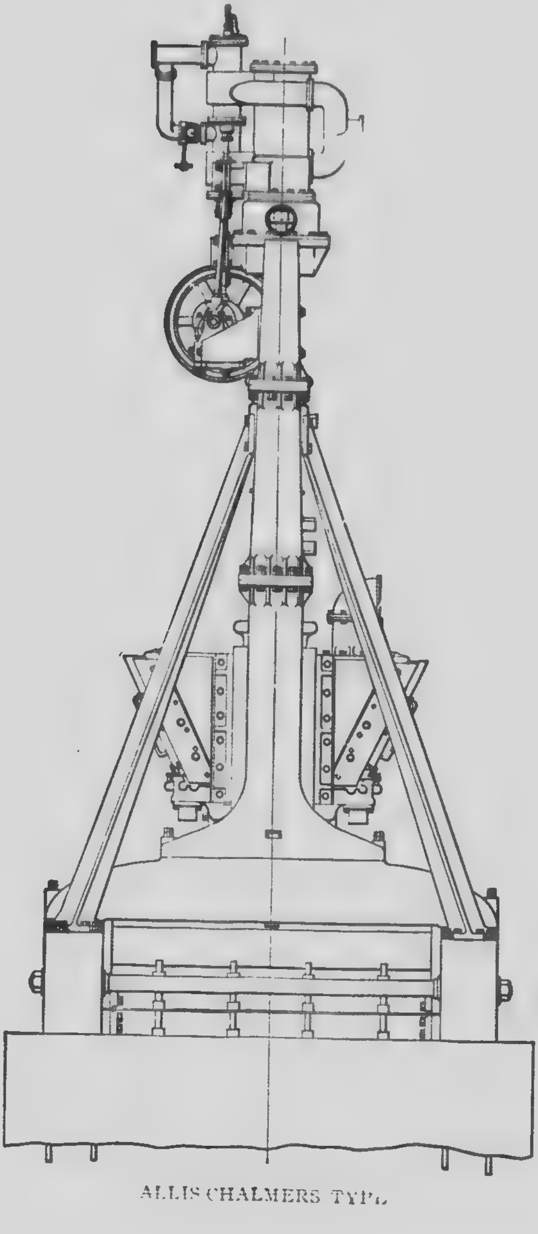
The mortar screen is made in sections; at the Quincy mill, out of five such sections, one of the central two has 1-inch openings while the others have ⅜ inch; it having been found that this arrangement relieves the mortar of nugget copper, which is unable to make its exit through the hydraulic (Krause) discharge. The mortar is also provided with a hinged screen which enables it to be opened for examination and closed again within five minutes. Formerly this required at least one-quarter of an hour. It is customary to open the mortar twice per shift, and oftener when anything goes wrong.

Difference of character in the copper ore affects the crushing of it and leads to a modification of treatment. Amygdaloid is not only easier to crush than conglomerate, but the copper does not enter so much into the harder portions of the rock as in conglomerate, where the hardest pebbles are intimately impregnated with the metal, and, therefore, require finer comminution. The later takes the form of re-grinding. This is today one of the principal problems of the milling practice, but it will be considered to better advantage when the representative mills shall have been described.

The Isle Royale is a comparatively new mill of three stamps, designed on lines which represent the outcome of the practice prevailing four years ago. Ore from the mines comes in hopper-bottom cars of 30-ton capacity. Sixteen to 20 of them arrive at the mill every 24 hours, to-



STEAM-STAMP OF 'IE



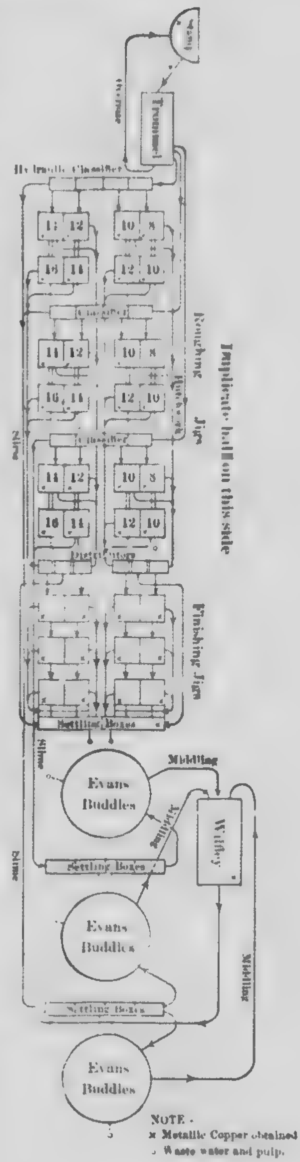
ALLIS CHALMERS TYPE

supply the single stamp now in operation. The capacity of each stamp is 550 tons *per diem*. From the bin the ore is fed, by gravity, along an iron chute, kept wet by a stream of water, so as to aid the descent of the material and wash down the fine stuff. A man with an iron rod, hooked at the end, watches the feed and regulates it, by holding back the ore on the chute or expediting it, as required by the stamp, the needs of which are indicated by the striki g of a 'bonnet' or coupling upon an iron rod whenever the feed is too low.

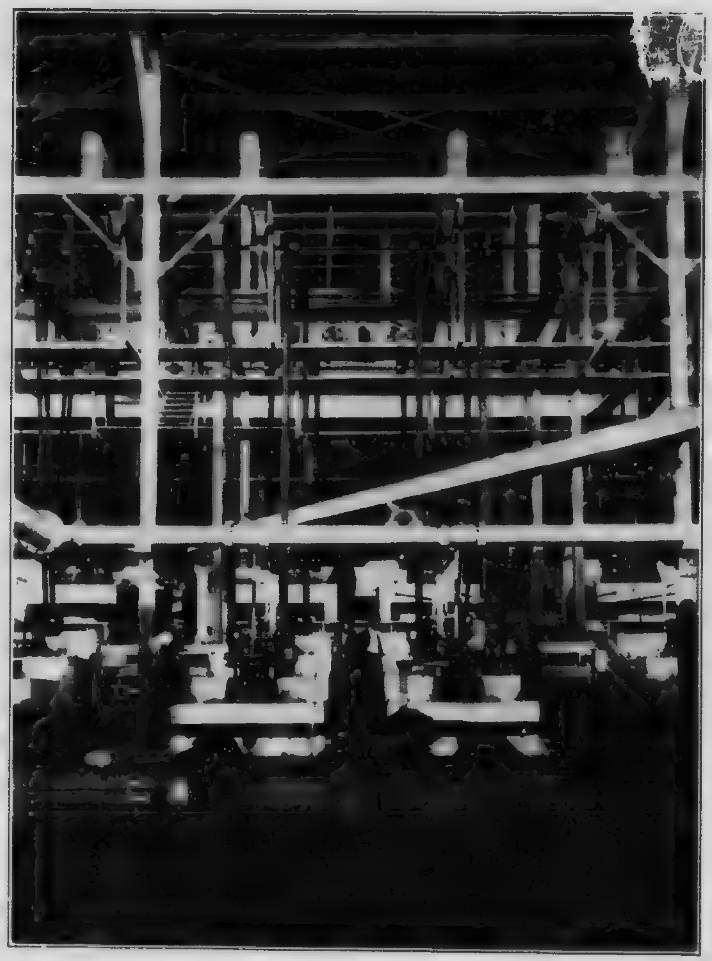
The stamp is driven, in its descent, by the piston of a steam-engine having a 20-in. cylinder and rated at 190 horsepower. Steam follows the stamp for about half the stroke, the head developing a maximum velocity of 25 ft. per second. The total falling weight is three to four tons. Each shoe weighs 800 lb. when new, and lasts about two weeks, by which time it has lost half its weight. Both shoes and dies are of chilled iron, made at the local foundry. The stamp drops 108 times per minute, a stroke or drop of 24 in. and an actual average stroke of 20 to 24 in., the difference being due to the thickness of the bed of ore on the die.

The mortar is circular and has a sectional lining which is renewed every 1½ to 2 years. Discharge takes place through a screen of punched steel-plate with holes ⅜ in. diameter. After passing through this screen, the pulp goes to two trommels, having ¼-in. holes, the oversize from which is returned (at the rate of about 7 tons per hour) to the mortar by means of a rubber belt-elevator. Removal of lump copper from the mortar is effected by a hydraulic arrangement known as the Parnall-Krause discharge. This device consists essentially of a stream of water fed by a 6-in. pipe, and entering through a 4-in. opening just below the lip of the mortar. The rising stream is under pressure sufficient to keep the rock from getting out of the mortar, while permitting the exit of the copper. The pieces of metal thus

extracted are termed 'headings.' About one-quarter of the total product of the mill comes out in this way; an equal proportion of the remaining copper is extracted between the mortar and the trommels, by a similar hydraulic separation acting through an inch pipe.



The scheme of treatment is indicated on the accompanying diagram, which illustrates one-half of a symmetric arrangement. The undersize from the trommels goes to a Tamarack hydraulic classifier, or spitzlutte, having four partitions. Four sizes are made; these go to a respective series of roughing jigs, of which there are six rows of four each. They are double compartment Collom jigs. Each yields its product of metallic copper; the overflow goes to waste, while the hutchwork passes on to the distributors which feed the finishing jigs; of these there are twelve, with double compartments. Here the product is again copper metal; the hutchwork goes to settling boxes; a portion is clean enough to go to the smelter; the remainder is re-treated;



INTERIOR OF TRIMOUNTAIN MILL

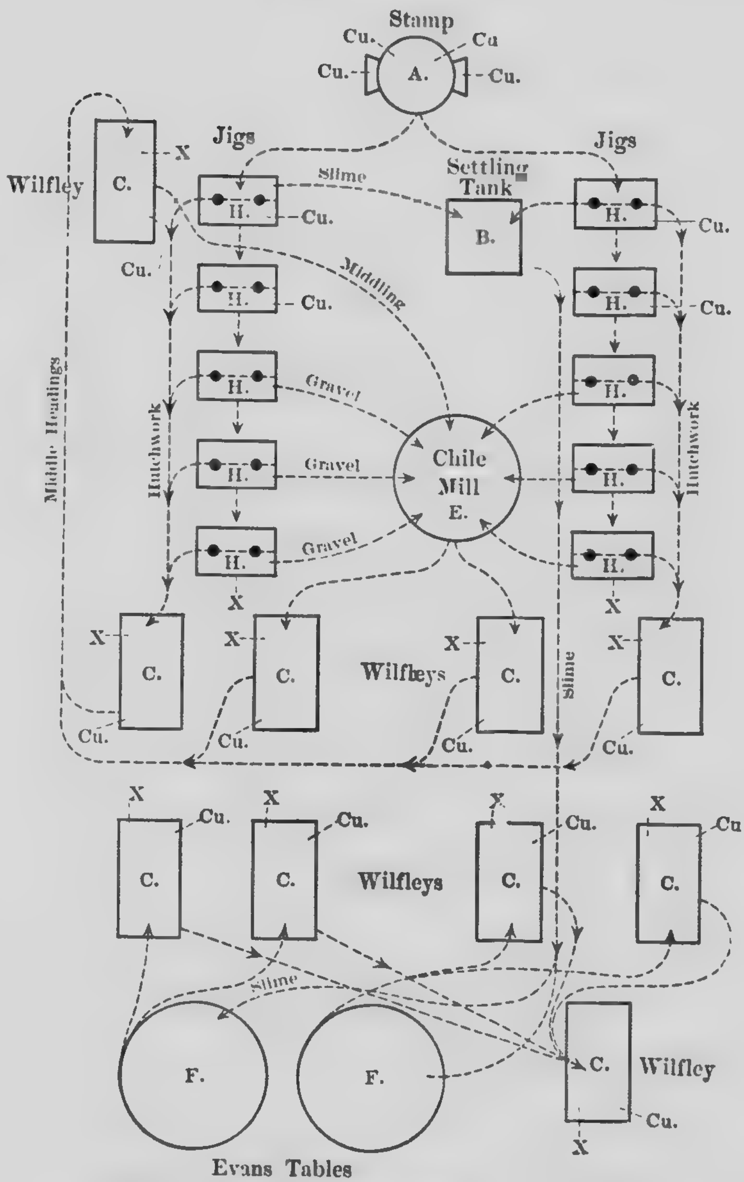
the overflow goes to the lake. Concerning the roughing jigs, it may be added that the first of these has an 8-mesh sieve followed by a 10-mesh in the adjoining compartment; the next has 12 and 14-mesh, respectively; the third 10 and 12; the fourth 14 and 16. In each case the screen is cut to a sieve 24 in. wide by 36 in. long. Returning to the classifier below the trommels; the slime proceeds to V-shaped settling boxes and is there separated; the overflow discharging into the lake, while the heavy goes to three revolving two-deck buddles known as Evans tables, the product of which is re-dressed on a Wilfley table, the tailing from this machine being returned to the Evans slime-tables. The Evans buddles have a cement surface, and their capacity is 12½ tons per deck, or 25 tons for the machine.

The 'ragging' from the second compartment of the roughing jigs is withdrawn through an air discharge and goes back to the stamp. This 'ragging' is the heavy copper-bearing sand lying immediately over the copper which concentrates on the sieve; it is essentially a coarse middling. The treatment of this material was the only attempt at regrinding in the Isle Royale mill at the time of my visit; but I am informed by the superintendent, Mr. J. G. Glanville, that rolls are now being installed to treat oversize from the revolving screens.

Another typical stamp-mill, crushing amygdaloid 'copper rock,' is that of the Quincy, on Torch lake. Mr. Jas. W. Shields is superintendent. There are two mills, one containing five heads, and the other three. In the old mill, each stamp has a crushing capacity of 475 tons, under a steam-pressure of 98 lb. per sq. in.; while in the adjoining new mill, a capacity of 550 tons is obtained with a pressure of 118 lb. of steam. New shoes weigh 708 lb. and last eight days, by which time they weigh 435 lb. The die weighs 800 lb., and lasts six to eight months; when taken out it weighs 225 to 275 lb. if it has worn evenly, the average being 250 pounds.

The stamps have an improved discharge for removing lump copper from the mortar, and there is a similar hydraulic separator below each of the trommels, to which the crushed ore passes from the stamp. The screen on the mortar is made in five upright sections or strips, one of them having openings of 1 inch, and the others holes of ⅜ inch. The larger screen-opening is found to be successful in relieving the mortar of lump copper which does not make an exit by the mortar discharge. From the stamp the ore goes to the two trommels, provided with screens having ¼-in. holes. In each mill the trommels are followed by classifiers and 24 roughing jigs, followed by more classifiers, the oversize going to six finishing jigs, and the remainder to two Wilfley tables. In the old mill, the slime, forming the overflow from the first classifier, goes to four settling boxes, or 'slime tanks,' and thence to six Wilfley tables. In the new mill, there are six Wilfley tables and one Standard table for treating the slime to each stamp, the head and middling from the set of six Wilfleys being pumped into a settling box, the overflow going to the waste launder, and the remainder to the Standard table, whence the tailing goes back to the 'slime tank' feeding the six Wilfleys, while the heading makes a copper product. The only re-grinding is done by a Chilean mill, of the Monadnock type, which crushes 60 tons per 24 hours, the material treated being the coarse middling from the last two series of roughing jigs, which, after passing through a 10-mesh sieve, is treated on jigs and Wilfley tables.

The Isle Royale mill represents the prevailing practice in the treatment of amygdaloid ores; that of the Calumet & Hecla, now to be described briefly, is representative of the accepted method of milling the copper-bearing conglomerate. The big plant of the Calumet & Hecla is situated on Torch lake, about five miles from the mines; it consists of two adjoining mill-buildings, both of them impressive on account of their size. As you walk through



SCHEME OF TREATMENT, CALUMET & HECLA MILL

them the amount of machinery seems unending; for one mill, containing 17 stamps, is 700 ft., and the other, with 11 heads, is 400 ft. wide, the length along the line of treatment being 175 feet.

The total capacity of the 28 heads, with an average of 300 tons per stamp, is over 8,000 tons per day. Owing to repairs and alterations, the actual scale of treatment is represented by 6,000 tons. The stamps are of the Leavitt type, and have a falling weight of 2½ tons, when the shoes are new. From the bin, the millstuff passes over a gently inclined iron chute, wide enough to serve as a sorting table, the ore sliding forward with the aid of a jerking movement, imparted by a crank at such a speed as to permit a man, who watches the feed, to pick out any lump copper.

The stamp is not turned mechanically, by the friction of the tappet and cam, as in the ordinary gravity stamp, but by impact on the ore lying upon the die; this turning is erratic being slight for one or two drops, followed by a sudden grand whirl, according to the state of the feed.

Removal of lump copper from the mortar is effected by a jig recently invented; this has its operating end inside the mortar. There is a slot, 1.5 in. wide, and 12 in. long, at the base of the screen and on each side of the mortar; under this there is a chamber, 4 in. by 12 in., bottoming upon a sieve with 1-in. openings; and this, in turn, lies over a larger compartment, divided by a double system of valves, so that the copper can be discharged through a gate without interfering with the work going on in the mortar itself. The plunger of this jig (there being one on each side of the mortar) gives an impulse which is transmitted through the water in the successive chambers; the smaller copper product (or 'hutchwork') passing through the lower sieve, with the 1-in. openings; while the heavier pieces gradually displace the gravel within the upper chamber (the top of which is level with the bottom of the mortar screen), until it is filled with lumps of metal. This is then removed,

without disturbing the wash of the stamp or jig, by opening the back of the receptacle, the contents of which are mechanically discharged into an intermediate compartment; and then, after closing the upper valve, through an opening which empties outside.

It is recognized that an excessive use of water is a bad feature of the local practice; and efforts have been made to obviate this defect. To this end, a jig-classifier has been devised to take the place of the V-separators in general use; and this has already diminished the quantity of water consumed by the milling operations. As the device is now passing through the Patent Office, no drawings are available, but the following description will indicate its nature: Two brass shields are placed within the body of the jig; these shields are elliptical in plan, and are placed one within the other at different heights above the jig-sieve; the outer shield extends into, and is sealed by, the jigging material (sand and gravel), so that the slime is prevented from rising within the shield, and flows along the sides until it escapes over the tail of the jig. The inner shield reaches down into the copper bed lying on the sieve; the sand and gravel entering under the outer shield, travel around the inner one, and finally make their exit also through a slot at the lower end of the jig, the slot being controlled by a gate which regulates the fluctuations of the load. This invention produces an economy of water because the classification is effected without the addition of any water except sufficient to run the jig; and, in fact, the slime is slightly de-watered by the settling action involved in the device. Less attendance, and no plugs to choke, are other noteworthy features of this arrangement, as compared with the usual hydraulic classifiers and V-shaped separators. By the use of the mortar-jig as against the Krause discharge, by the aid of the jig-classifier just described, and by a marked decrease in the number, and increase in the efficiency, of ordinary jigs at work in the mill, the consumption

of water has been lowered from something like 2,500,000 gal., to 1,125,000 gal. per stamp per 24 hours.

The scheme of treatment is given in the diagram on page 131. This shows (wherever Cu appears) the stages at which the metallic copper is extracted, and the gradual elimination of the encasing rock. (Wherever X appears there is a product that goes to waste.) At the stamp there are two extractions of copper on each side of the mortar, as already described. On making its exit through the screen, the pulp is divided so as to pass through two series of double compartment jigs, five on each side. The first two jigs have sieves 24 in. wide and 36 in. long; the next three have sieves 50 in. wide and 30 in. long; the jigs are arranged so that the compartments are in series along the course of treatment, the pulsation being along the line of flow.

The slime separated in the first jigs, by the classifier already described, goes to a settling tank and thence to two Evans revolving tables of four decks each, the partial concentrate from these eight 'buddles'—as they may be termed—passing to four Wilfley tables, the middling from which goes to a fifth Wilfley. Metallic copper is obtained at each of the Wilfleys. Returning to the jigs: metallic copper is secured at the first two of each series, the other three yielding 'gravel,' or middling, which goes to a Chilean mill for re-grinding. The hutchwork from all the jigs, goes to two Wilfley tables; and the crushed middling from the Chilean mill goes to two other Wilfleys, the middle heading from all four being returned to a fifth, the middling of which in turn goes to the Chilean mill. Metallic copper is obtained from each of these Wilfleys also. The tailing from the mill is elevated by raff-wheels of 50 ft. and 60 ft. diameter; it is tested by taking automatically, and at regular intervals, a sample which is assayed for its copper contents, and passed through successive sieves to determine the character of the crushing.

Losses in milling of these copper ores are attributable

to two causes: the first is the abrasion of the metal due to its being retained within the mortar after it is released from the encasing rock, the rate of discharge being disproportionate to the enormous rate of crushing; the second cause is the existence of copper within particles of rock which have been inadequately crushed; this is especially true of conglomerate, in which the metal penetrates the very body of the hard pebbles. The copper exists in particles ranging from the microscopic to massive; therefore, the crushing can be likened to the breaking of nuts, the kernel being liberated by the cracking of the shell; but the nuts range from filberts to cocoanuts in size, and from peanuts to brazils in hardness. Re-grinding, therefore, is an important problem.

At present it is the practice, in many mills, to return the oversize from the trommel back to the stamp, which is a clumsy solution of the difficulty, because much of the pulp simply travels the circuit. However, only a small proportion of the pulp can be re-ground profitably, under existing conditions, by reason of the high consumption of power and the excessive wear and tear involved in all re-grinding machines. It can be said that only material carrying 0.50 to 0.75 per cent copper, or more, will pay to treat in the Chilean mill—which, at present, holds the field.

At the Baltic mill, where this practice was first used in the copper country, 120 tons of oversize from the trommels of one unit is passed through rolls; and this expedient has raised the crushing capacity of the stamp just that amount —120 tons per day. At the Calumet & Hecla plant, the Heberle mill, consisting of two steel disks, eccentric to each other, and revolving in opposite directions, is used; but the superintendent is in no way enthusiastic over this machine. High-speed rolls and Huntington mills have been employed; at present the Chilean mill, both the Monadnock and the Allis type, form part of the equipment, and they are said to do good work. But their capacity is small, namely 33

to 40 tons per 24 hours of the material known as 'ragging'; this ranges from 3-16 in. downward, and is re-ground through a 16-mesh screen. They consume an excess of power—28 h.p. per mill, equivalent to from 15 to 20 cents per ton. In the Quincy mills the Monadnock type of Chilean mill, 6 ft. in diameter, is in successful use. Each machine consumes 25.61 h.p., and crushes from 55 to 60 tons of amygdoloid per 24 hours through a 10-mesh screen. The product is granular and in good condition for the Wilfleys. At the Baltic, the 6-ft. Huntington mill, also working on amygdaloid, puts 51 tons of ¼-in. material through a 16-mesh screen in 24 hours. Therefore, allowing for the difference in screens, the Huntington appears to grind faster than the Chilean mill working on similar material. The Baltic mill has one Huntington to four stamps; this machine treats the 'ragging' from the finishing jigs. In this mill, rolls are also used early in the operation, the oversize from trommels does *not* go back to the stamp; from the trommel with ¼-in. openings, the oversize passes to Sturtevant rolls; and from them it is returned to the trommel, to take its regular course through the plant.

From indicator cards it has been shown that the Chilean mill takes 25 to 30 h.p., and the ordinary Huntington 14 h.p. even where the latter is doing more grinding. The former makes 26 to 30 revolutions per minute, the latter 60 to 65. The consumption of steel amounts to about 15 cents per ton in the one case, and 2.25 cents in the other. That is on amygdaloid. The total cost of re-grinding coarse 'ragging' may be put at 10 to 12 cents per ton for the Huntington, and 30 to 35 cents for the Chilean.

The roller of a Chilean mill has a crushing weight of about 6,000 lb., this being the actual weight of the roller, plus one-third the weight of the spider and the tire. The roller in the Huntington weighs 1,400 lb., but by reason of the centrifugal force developed by the greater speed of revolu-

tion, the virtual crushing weight of this is approximately 5,400 pounds.

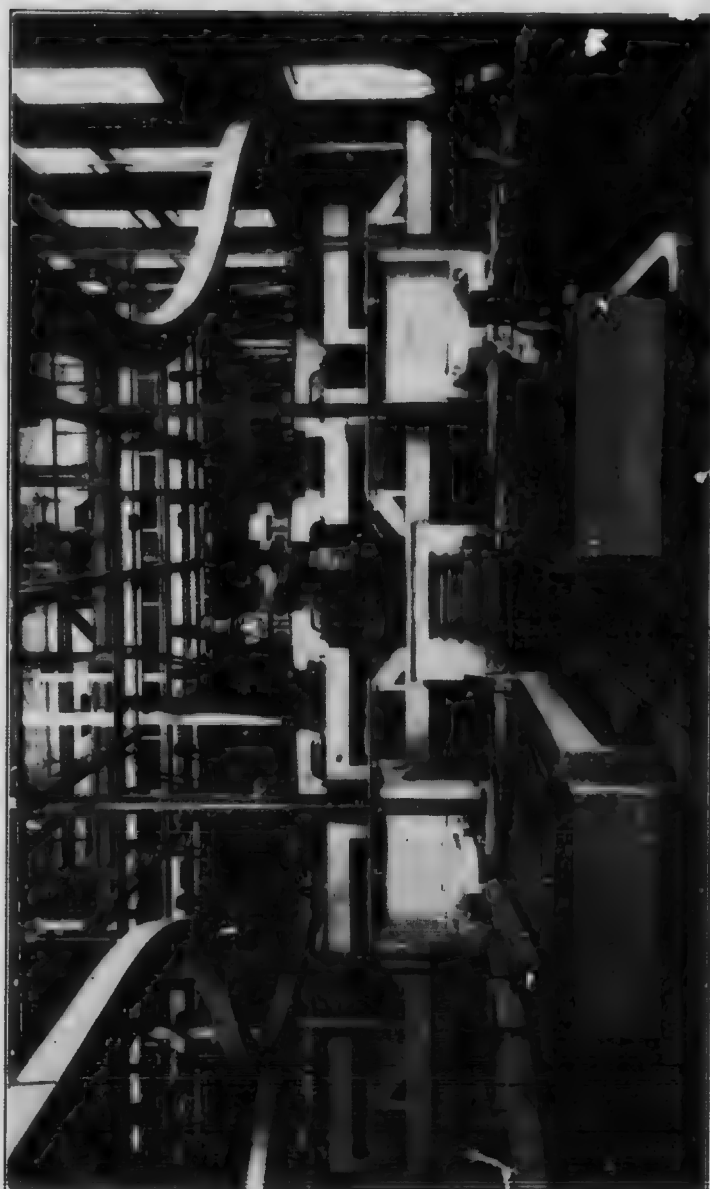
The new Huntington mill, now being introduced, has the same diameter as the one previously in use; but it is a more powerful machine, with overhead drive, and is heavier, weighing 45,000 lb., as against 26,000 lb., the weight of the usual 6-ft. machine. This increase in weight was made in consequence of experience obtained by Mr. Frank Klepetko in the concentrator of the Boston & Montana Copper Company at Great Falls. In leaving this part of the subject, it may be pointed out that re-grinding machinery in a mill serves as a valuable cover to any erratic behavior on the part of roughing jigs or other devices doing similar work.

It is difficult to secure accurate data concerning the tailing losses. On amygdaloid, the Osceola tailing averages 0.018 per cent from an initial one per cent ore, making the extraction 82 per cent. At the Adventure, with 0.95 per cent ore, the tailing average is 0.26, giving an extraction of 73 per cent. At the Champion, with ore carrying 30 lb. of copper, of which 4 lb. is 'mass,' sorted out before milling, the tailing ranges from 0.30 to 0.35 per cent, equal to an extraction of 80 per cent. At the Quincy, the mill-rock contains 19.3 lb. copper per ton, and the tailing averages 0.26 per cent, indicating an extraction of 83 per cent. Speaking generally, it can be said that in treating an amygdaloid containing 1 to 1.5 per cent copper, the tailing averages 0.25 to 0.35 per cent, this being equal to an extraction of 75 to 80 per cent. On conglomerate such as that of the Calumet & Hecla, the included copper carried away in the tailing precludes a high extraction, a loss of 0.7 per cent indicating an extraction of 72 per cent on a 2.5 per cent ore.

The mill treatment, therefore, is not satisfactory; it has not, for example, kept pace in improvement with the mining methods of the region. The present practice is really to drown the ore with an enormous volume of water.

not in the mortar alone, but also in the hydraulic classifiers. This is required to aid the discharge from under the stamp, and to convey the crushed material through an interminable number of jigs. The stamp does not pulverize, it does the work of a rock-breaker, for it reduces only to ⅜ inch. For this work, as also for the other extreme—very fine grinding—the stamp is not adapted. But effort toward betterment is under way, and a radical departure from established practice proves that prejudice is not to cripple advancement. At the Champion mill, under the experienced direction of Mr. F. G. Coggin, gyratory crushers are to be tried, supplemented by rolls. A unit of equipment, capable of treating 350 tons per day, is now in course of erection. This scheme of treatment will be based on the gradual reduction of 'copper rock' through Gates gyratory crushers, to a size suitable for further reduction by rolls instead of steam-stamps, the idea being that if the ore can be sent to the mill already reduced to a size of 2.5 in. or less, the expensive steam-stamp is not needed. The saving to be made in this way, will consist of a decrease in the power required—at least 75 per cent—a smaller consumption of water in the process of separation, and a diminution in slime, which does not exist in the broken rock as delivered to the mill, but is made chiefly by abrasion with the lump copper in the mortar. It is also intended to jig the material coarser than the present size, which is ¼ inch, in order to allow some of the coarser stuff to escape as tailing without further reduction; that portion requiring further comminution will become 'middling' from the jigs, and will be reduced by regrinding machinery.

The general scheme involves the use of gyratory crushers at the mine. There is one of these at the Champion mine already; it is the 'No. 7½ Gates,' and has proved a satisfactory machine, being better adapted to the crushing of rock containing lump copper, than the breakers with straight jaws. It is intended to erect a larger gyratory at the



INTERIOR OF BALTIC MILL.

mine, so designed that the spindle can be dropped one inch, ereby overcoming the delays due to the clogging of the crusher by lumps of copper. The jaws of this crusher will be set 2.5 in. apart. It is not practicable to dump the skip or car direct into the crusher, as at the Homestake, on account of the presence of lump copper, which requires that the ore shall pass over grizzlies and undergo sorting by hand. Under the gyratory will come a conveyor, with boys to pick out pieces of copper which have been released by the passage of the rock through the crusher. Then the material passes to bins which load into cars that go to the mill. At the mill, the bins will deliver to a shaking grizzly, the oversize going to a gyratory—set at 1.5 in.—the product from which will join the undersize from the grizzlies to be elevated to a trommel, with ⅞-in. apertures. From here the material goes to roughing jigs; the oversize and undersize, respectively, from the trommel going to separate jigs, and from them to separate rolls. Thence the product is raised to three trommels, with ⅝, ⅜, and ⅛-in. openings, all the product, as sized, passing to different jigs, except the screening from the last trommels, which goes to cone-classifiers. At the last set of jigs, a middling will be made; and this will go through rolls before being fed to the new Huntington mills, the product from which will join the fine screening from the last trommel, to proceed to cone-classifiers and thence to Overstrom tables. Experiments with this concentrator have given excellent results.

By these changes it is expected that the Champion will decrease the cost of milling, and secure an increased amount of copper, possibly equal to the present total cost of milling, 25 cents per ton. This will emphasize the observation that during late years the endeavor to lessen costs has been pushed at the expense of any improvement in extraction; that is, it has not been realized that while the expenditure entailed by the treatment of copper ore has decreased, there has been no commensurate diminution in the amount

of copper lost. Five cents worth of copper, per ton, lost in the tailing is worth just as much as a five-cent decrease in milling cost. It should be added that the installation proposed is purely experimental, but the intention is to put a definite tonnage through a definite process; in other words, the experiment is on a commercial scale. The design of the experimental plant is purposely made sufficiently flexible to permit of any modification, the necessity of which may be indicated by the results. There is nothing revolutionary in the scheme of treatment. It is simply an application, to the special conditions in the Lake Superior district, of methods which have been adopted in Montana and Colorado. Whatever the outcome, it is evident that this is a departure from precedent which is entirely justified; it starts an investigation of current practice such as should contribute notably to the empirical development of milling methods in the copper regions of Michigan.

XIII.—Smelting Practice.

The treatment of ore at the mills yields a product which consists of those various grades of metallic copper called 'mineral.' Some of the mills make as many as five classes, removed at different stages of the dressing; these vary as regards fineness of particles (from slime to walnut size), and as regards purity (from 30 to 75 per cent copper). There is also a large proportion of pieces of fragmental copper extracted from the mortar, called 'headings.' This is almost clean metal, containing about 95 per cent copper. By hand-sorting at the mine, and at the mill (as the 'rock' is fed into the stamps) there is secured a product called 'barrel work'; this ranges in size from fragments as big as an orange to pieces as large as a man's head. Exactly similar material sorted out at the mine, but ranging in size from a few pounds to several tons in weight, is known as 'mass.' The 'barrel work' and 'mass' contain about 70 per cent copper. Thus, the material which reaches the smelter includes copper in a great diversity of shape, purity and degree of subdivision. On the whole, the average is 60 to 70 per cent copper, with an admixture of heavier constituents of the lode-rock, forming a chemical complex which is mainly aluminum silicate together with varying proportions of iron and lime.

Ordinary custom charges for smelting are $8 to $9 per ton of 'mineral,' with 5 cents penalty on each unit below 70 per cent copper; the average cost of smelting is therefore about $7.75 per ton of refined copper; the lowest cost, at the Quincy works, is $5.25, and at Buffalo, $5.35 per ton.

The smelting is essentially a melting and refining of a copper product in which the copper is in metallic form mixed with a relatively small percentage of rock impurity. This main operation takes place in a reverberatory; it is sup-

plemented by the reduction of the resulting slag in a blast furnace, yielding copper blocks which are returned to the reverberatory furnace to be refined.

The Quincy smelting works are representative of the practice which has prevailed during the last twenty years. This plant is situated on the foreshore of Lake Portage, at Hancock. To Mr. W. P. Smith, the superintendent, I am indebted for every facility for observation, supplemented by courteous explanation.

The product from the mill is discharged from the railroad cars into a storehouse, the 'mineral' arriving in barrels which are emptied into trucks; these pass into the furnace building, where they are raised by an electric crane, so that their contents drop into a hopper situated over an opening in the roof of the furnace. The smaller 'mass' is thrown by hand through the side door of the furnace; and when the lumps are too big for entrance this way, they are lowered by an electric crane through the roof-opening. In starting a charge, a small amount of 'mineral' is spread over the bottom; then the heavy pieces of 'mass' are lowered carefully upon this bed. Sometimes an unusually large mass will not permit of even this mode of entry; then it is laid aside until, repairs to the brickwork becoming necessary, the furnace is dismantled; this permits of the mass being placed on the hearth while the top of the furnace is rebuilt over it.

Each of the four reverberatory furnaces has an average capacity of 400 tons of 'mineral' per month of 24 actual working days. A charge of 36,000 lb. mineral is treated every 24 hours by each furnace, the product being 26,000 lb. copper. The hearth is 12 by 18 ft. As soon as the charge is introduced, the melt begins; after a couple of hours the skimming of slag commences. About 15 to 16 hours are required to complete the treatment, the remaining 8 or 9 hours being consumed in poling, ladling, cleaning up and re-charging the furnace for the next melt.

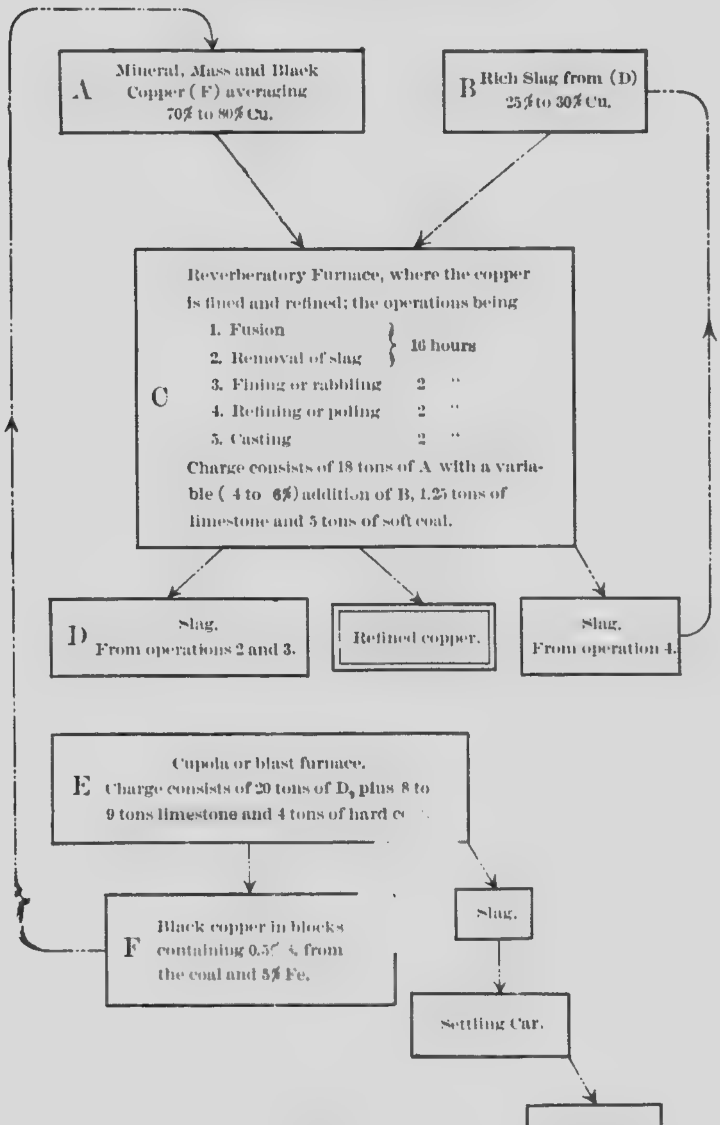


DIAGRAM OF OPERATIONS AT
QUINCY SMELTER.

After the charge has become thoroughly melted, and the slag has all been removed, it is 'rabbled' for 1½ to 2½ hours to oxidize and convert into slag the impurities contained in the copper. This 'rabbling' is effected either by flapping the surface of the molten copper with an iron tool called a rabble, or by blowing into the copper a jet of steam or air. The use of the latter is the most common. Two to four ¾-in. pipes, supplied with air at 60 to 90 lb. pressure per sq. in., are thrust into the liquid copper, resulting in an active agitation of the whole charge, thereby constantly exposing fresh surfaces of the metal to the oxidizing influence of the furnace atmosphere. When this operation is complete, as judged by the refiner from the character of a sample taken, the surface of the charge is again skimmed clean; then poles of wood, usually poplar, 16 to 20 ft. long, are thrust into the copper to reduce the copper oxide formed during the 'rabbling' operation. This last operation is called 'poling' and requires about two hours. Not quite all of the copper oxide is reduced; merchantable copper always containing about 0.5 per cent Cu_2O.

The ladling then follows; the liquid metal being poured either simply by hand or with mechanical aid. At one furnace the ladle was hung on a traveler, permitting of adjustable leverage, and readily controlled by the workman, so that each of two men alternately dipped a ladle holding 90 lb. copper, the dipping being finished in 1½ hours; at another furnace, on the other side of the building, I witnessed the older fashion of hand-pouring with 30-lb. ladles, three men requiring three hours to 'dip the charge.'

The slag from the reverberatories contains 12 to 18 per cent copper; it is drawn off into pots, which go to a blast furnace; but the richer slag, skimmed after the final poling and containing 25 to 30 per cent copper, goes back into the reverberatory and forms part of the succeeding charge. The blast furnace is a cupola, 38 by 76 in., of standard type; it is operated intermittently, as material for it accumulates.

Lime is added to flux the reverberatory slag and the ash from the fuel consumed; the usual charge contains 20 tons of slag, with about 40 per cent lime and 22 per cent hard coal. The slag from the cupola contains an average of 0.6 to 0.75 per cent copper. What copper it does contain, is half in the form of 'prills' or globules of metal, and the remainder is disseminated unreduced copper oxide.

The copper from the ladles is poured into moulds of varying shape, which in turn are emptied into water to cool; any excrescences are chipped off, and the metal then goes to the warehouse ready for shipment to the market. Four differently shaped products are made: 1. Ingots and ingot bars, each ingot weighing 20 lb., and each bar 60 to 90 lb.; these are suitable for casting and for use in brass-making, etc. 2. Cakes, 100 lb. to 4,000 lb., as required by customers; this material is employed chiefly for rolling into sheet copper. 3. Wirebars, 3 to 4½ in. square and 3 to 7½ ft. long, weighing 100 to 480 lb.; these are for manufacturing wire, suitable for electric and other purposes. 4. Anodes in plates about 2 ft. by 3 ft., 1¼ in. thick, weighing 250 lb., which are smelted from picked 'mineral' containing 60 to 70 oz. silver per ton; the two metals are subsequently separated by electrolytic refining.

The first three of the copper products have a conductivity of at least 99. The reverberatory furnaces have to be repaired every eight or ten weeks. The furnace roof lasts about eight months and the fire-box roof half that time. Several additions and improvements are being designed, especially for the discharge and storing of 'mineral' as it comes from the several mines which are contributory to this smelter. In default of any systematic sampling, it is difficult for the smelter manager to arrive accurately at the metal contents of the material he treats. The 'mass' copper is extremely irregular in shape, and carries a varying proportion of adhering rock. Even the 'mineral,' which comes in barrels, is difficult to average, because any single

barrel may contain several grades of product in layers by no means parallel to each other, so that the 'tester' used at the mills will give an inaccurate result. I watched several barrels while they were being emptied, and noted that they contained a mixed product thus carelessly arranged. This part of the operation merits keener attention, and will require it if the smelter is to check the work of the mill.

On the other side of Portage lake and about three miles west of Houghton, there is the new plant of the Michigan Smelting Company, an enterprise organized to treat the product of the mines on the South Range. This smelter had just been built within the preceding twelve months, despite the severity of the winter cold, and represented the outcome of unusual energy and skill. Although a temperature of minus 20° F. was not uncommon during the period of construction, and minus 10° F. was considered relatively mild weather, the walls and foundations do not appear to have suffered. The accompanying plan explains the arrangement of the plant. To Mr. F. I. Cairns, the manager, I am indebted for many of the details which follow.

The works are built upon a terraced slope, the copper product from the mills being delivered by the railroad in bottom-dump cars sufficiently tight to render the finer stuff safe from leakage. The 'mineral' is dumped into a dryer, a rotating cylinder slightly inclined, 72 in. diameter and 30 ft. long. This dryer is the A 9 machine of the Ruggles Cole Engineering Company, and has a capacity of 15 tons per hour. Drying is required in order to prevent the freezing of the 'mineral' in the bins during winter, and also to facilitate sampling. 'Mass' and 'barrel work' copper are neither dried nor sampled, but are sent direct to the melting furnace.

After sampling, the mineral goes to the bins; they are vertical cylinders of sheet steel, 12 ft. diam. and 30 ft. high. The design of them is borrowed from grain-elevator prac-

tice, such as is to be seen on the outskirts of Chicago. This form of construction is best capable of taking the strain developed by the outward pressure, which is carried by the tensile strength of the steel plates, the high density of the mineral rendering wooden bins of ordinary construction inadequate to the purpose. These bins are 10 in number and hold 250 tons apiece. From them the mineral is taken in bottom-dump cars along a track above the smelting furnaces, to be discharged into the latter through hoppers.

There are three smelting furnaces, each having a hearth 18 ft. wide and 50 ft. long, with a daily capacity of 100 tons of mineral averaging, say, 50 per cent copper. It remains to be seen what the furnaces are capable of doing, but 150 tons is regarded as a reasonable maximum capacity. Some iron was added at first, say, up to 6 per cent, in order to take off the excess of alumina in the rock impurities accompanying the mineral. This iron was a hematite from Crystal Falls, and was considered to insure a more liquid slag than if entire dependence were put on the lime present in the 'mineral.' But this addition of iron has been found unnecessary. Slags contain 15 per cent alumina, and there is enough lime in the charge to keep them liquid. Thirty tons of mineral are fed into the furnace at a time, the resulting metal being supplied to the 'casting' or refining furnace intermittently in charges of 50 tons.

Since writing the above it has been found advisable to reduce the size of the melting furnaces, from 18 ft. wide by 50 ft. long, to 16 ft. wide and 35 ft. long. In the furnaces as first built, the sand bottoms gave a good deal of trouble, due principally to the great expansion of such a large furnace. The expansion of this large copper-soaked sand-bottom was found to be very much more than that of a similar sized furnace smelting for copper matte. The consequent expansion (and contraction of the furnace on cooling) resulted in cracking and weakening the bottom; so that, with a bath of metal of such high specific gravity

THE MICHIGAN SMELTER.

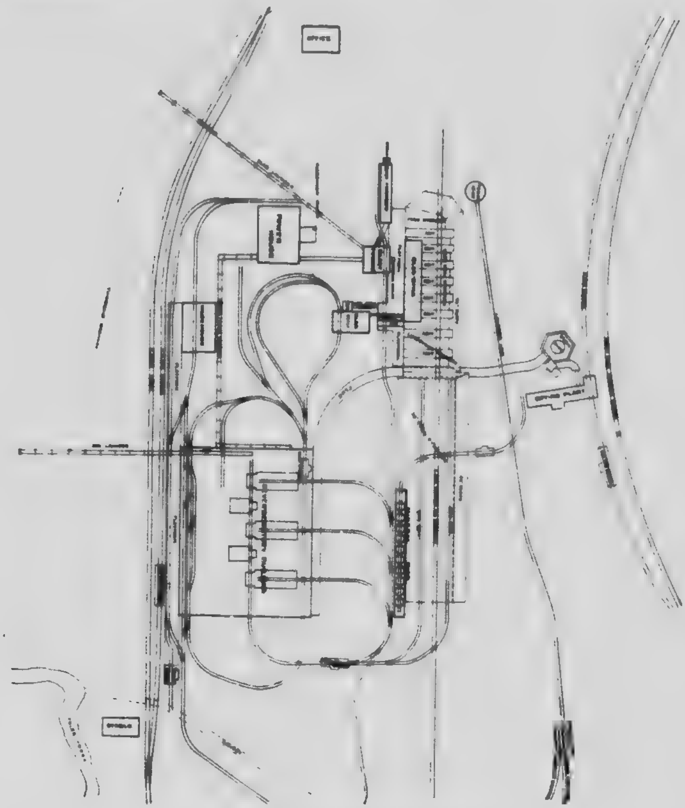
as copper upon it, there was a great tendency for the bottom to float. Several bottoms suffered in this way; as a consequence, the furnaces were reduced in size, as noted above, and the bottoms were laid of two courses of 12-in silica fire-brick in an inverted arch. Absolutely no difficulties have been encountered in the operation of these furnaces since then, and they have resulted in a marked economy in the treatment of the 'mineral.'

The copper runs from the melting furnace to the refining furnace, which is 5 ft. lower, along a launder 21 ft. long, there being no trouble in keeping the metal liquid for this distance. There are two refining furnaces, each with a hearth 14 ft. wide and 23 ft. long, and so arranged as to take the product of the three melting furnaces, the central melting furnace of these tapping to either of the refining furnaces. At present the two casting furnaces together treat two charges per day; but this rate of operation will be expedited when the plant gets into full working order.

The slag from all the reverberatories goes to a blast furnace of standard design, 38 in. by 120 in. Slag is skimmed into large cast-iron rectangular pots, 10 in. by 24 in. by 60 in., holding 1,000 lb., which are carried on trucks and drawn by an electric locomotive to the rock-breaker, a 15 by 30-in. Blake crusher. The pots are emptied into the jaws of the breaker, by an overhead pneumatic crawl; the broken product is sampled before being elevated to the bins above the blast furnace. The copper from this furnace is cast into moulds, chilled, and then transferred to the refining furnaces by electric traction and crane. The slag from the blast furnace is granulated in flowing water, and then run out by launder to the lake.

In the large furnace-house there is a traveling electric crane, so that, what with the fullest use of gravity and mechanical devices generally, there is the least possible amount of manual labor employed in the handling of material. The chipping of the ingots, to take off excrescences,

is done by hand, though it might well be done with a pneumatic chisel, the compressed air for which is already available.



PLAN OF MICHIGAN SMELTER.

It will be seen from the descriptions of the two establishments, one old and the other just built, that the essentials of the smelting operations have not been changed in the new works; these, however, exemplify the constant effort of the modern engineer to eliminate manual labor from all mining and metallurgical enterprise.

XIV.—The Men Who Did It.

Nature gave the Upper Peninsula a great series of copper lodes. Man turned them to the use of his kind. As I would choose the region by the Lake as a type of American mining at its best, so I would instance the character of the men responsible for its development as representative of that composite energy which has conquered the wilderness of plain and forest, changing the desert to a granary and the waste to a habitation. Whoever desires to appreciate the causes which have brought about the great growth of these United States can, by going to Houghton and Calumet, observe two of their chief factors, namely, the natural resources of a continent and the best blood of many races, united in effort and competing in skill. It needs but to sound the roll-call of inventors, engineers and business men, who have won distinction in the copper country, to bring out the fact that many are the peoples who have partaken in this industrial conquest. The steam-stamp was the invention of Ball, a Massachussetts mechanic; the vanner is to be credited to William B. Frue and his master mechanic, William Foster, of Fredonia, New York; Frue, who was an Irishman, found the Pewabic lode and the South Pewabic, two discoveries which became identified with the Quincy and Atlantic mines, respectively. August Heinback, a German, did much to develop the application of the vanner; the jig was developed by John Collom, a Cornishman, whose name still clings to that device. J. W. V. Rawlins, an engineer with mechanical genius, was an Englishman, while S. E. Cleaves, a notable character and the first to make an iron-bodied jig, came from Maine; Philip Scheurmann, a pioneer millman, was a German; Mr. Bruno V. Nordberg, the designer of many of the most important installations of machinery, is a native of Finland; Mr. John Stanton, identified with all that is sound in mining,

QUINCY HILL AND PORTAGE LAKE, FROM SOUTH SHORE.

was born in Somerset, England, while Mr. E. D. Leavitt, Jr., another engineer who has taken a notable part in the equipment of the big mines, is of Massachusetts; and if the roll begins as it ends with the name of a New Englander, it serves as a suggestion of that little leaven that leaveneth the whole lump.

Of mechanical ingenuity there has been great diversity of origin, but underground one race of men has held and continues to hold—pre-eminence. The Cornishman is without honor, save in his own country; there his obtuseness to the application of modern machinery has passed into a proverb but outside the rock-ribbed peninsula of Cornwall, elsewhere, all over the world, he has taught the rest of mankind how to mine. The story of the Lake mines is punctuated with the names of the 'captains' whose inherited skill has piloted those that explore the dark mazes [illegible] world.

> "By Tre, Pol- and P[illegible]
> You may know the Cornishmen"

and, if these prefixes are not sufficiently indicative, you can trace them by the stories of their physical strength and good humor. They say that [illegible] Martin Goldsworthy had been slanged by a dismissed workman, he was asked why he had not knocked the man down. With a strong aspirate he replied, "That's one of the *h*onors of the position." Then was Capt. William Parnall, one of the old guard, who crossed the Atlantic when but a boy of 18, prompted to emigrate by reason of a poaching escapade. He served in the water works tunnel at Washington, and became known as an expert [illegible]man. After two years in the coal and iron regions of the South, he came to Lake Superior, in 1859. From w[illegible] at the National mine, he soon became shift-boss, and then assistant captain. He became celebrated locally as a wrestler, particularly through a fight in which he vanquished a notorious bully. This event drew him to the attention of Capt.

THE BALTIC STEEL DAM.

John Chynoweth and other older men, who advised him to improve his natural abilities. He used to read at night, lying in his bunk with his miner's candle stuck in his hard hat, and that after an exacting day's labor! From being captain at the Franklin, in 1869, he advanced to posts of greater importance; and in 1890 he was appointed assistant superintendent at the Tamarack; he died, in 1903, the chief at that mine. He was recognized as a progressive man, willing always to take a sympathetic attitude toward technical science, as is proved by the fact that two of his sons were graduated with the first class of the Michigan College of Mines, in 1888. Richard Uren and John Uren were also men whom change did not stagger; they were willing to move with the procession, sometimes to lead it. Capt. Richard Uren, who died in 1897, possessed a good deal of mechanical ingenuity, and busied himself with improving the devices used around a mine. He, like most of his countrymen, traveled to different districts; as superintendent of the Old Abe mine in the Black Hills, he became familiar with gold mining in South Dakota; later, he was one of the first to open up the Wolverine; and there is no reason to doubt that, if his ideas had been followed, the Wolverine would have become a big mine many years before Mr. Stanton actually accomplished that feat. Capt. John Daniell, who also died in 1897, was the originator of the Tamarack 'deep-level'; simple though it seems today to sink a shaft 2,300 ft., to cut the Calumet & Hecla lode, it was a bold venture in 1884. Another good service he did was in advising Mr. Albert S. Bigelow to interest himself in the Boston & Montana group, at Butte. He was a good man underground, and had that sound judgment which is priceless; he was the man who made the Osceola a paying mine, when others had failed; although not a technical man himself, he gladly availed himself of technical science. Among the living are such worthies as Capt. Samuel B. Harris and Capt. Johnson Vivian, who have re-

THE MICHIGAN COLLEGE OF MINES.

tired, but live in comfort amid the scenes of their past activity. Capt. James Chynoweth is one of the survivors of this notable group, and has charge of the Centennial, Allouez and other mines. Captains John Dennis of the Adventure, Joshua Hooper of the Victoria, Richard Edwards of the Isle Royale, and Thos. Hosking of the Franklin, have also done credit to 'the old county.'

It is a notable fact that, in the first class sent out from the Michigan College of Mines, there were five sons of Cornish mine captains, out of the seven who were graduated. The day of the Cornish mine captain is vanishing; his place is being taken by sons who are native Americans; but these, despite their better education, lack the distinctive character of their forefathers, losing some qualities and gaining others better suited to their environment. Nevertheless, even today, when technically educated men—American, whatever their fathers were—direct the operations of the mines, I found the underground work in charge of a Cornishman, *in every instance.* Shoved aside at surface in the march of scientific progress, he holds his own underground, simply because he knows better than anyone how to break rock, how to timber bad ground, and how to make the other fellow shovel it, tram it and hoist it. At the Atlantic I heard a story on Capt. Vivian, which that worthy gentleman will forgive me for quoting. A friend of his told it thus: "Cap'n Vivian took hold of the Franklin when she was dead to the world, and she just scraped along for a while. He was talking to the agents up at Calumet one day—they had a kind of party and were gassing a bit, he told them the Calumet could run herself, she was rich enough not to need much bossing. 'A good bal makes a good cap'n,' said he. They didn't get much of a joke on the old man; he left them chewing." It is true enough; there is the chairman, there is the general manager, the accountant, the engineer, the assayer, the manager—and it is the boss *underground* that makes the mine. But it

takes the other people to turn the ore *when mined* into money; and here is where the Cousin Jack has too often failed to equip himself. There is the miner's strength and skill in the Cornishman's arm; he is the hammersman of the world—I mean underground, not among the artificial conditions of a farcical drilling contest—but he lacks the ability to keep his eye on the main thing, the dividend. Hence, many of them are good shift-bosses, but poor general managers. At Houghton they tell the story of the easy-going captain who used to visit a certain mine at regular intervals. Driving up to the office he would call for the man in charge of the work, and say, "Good mornin', Cap'n; how is that drift going north from No. 3 shaft (or any old shaft)?" To which would come the answer, "She's lookin' keenly, Cap'n. There's a lot of copper in 'er." "What the blooming 'ell is the use of copper down there? Send 'er up, send 'er up." A crack of the whip and he was on the way back to town. Of course, I do not mean by this that the Cornishmen, as managers, had no sense of duty; but they did lack that nose-to-the-grindstone strenuous application which makes the modern American ruminate mining and machinery, while Englishmen are playing cricket or golf, and Germans are drinking beer or singing college songs. They are all part of life—the song, the play and the work; but, assuredly, to win that share of money and position which constitutes success, it is necessary to play the man, and strong in will "to strive, to seek, to find, and not to yield."

XV. A Last Glance.

My story is almost at an end. It has necessarily been too short to do justice to so wide a subject; but it will, I hope, convey to those who have never been to these splendid mines, some idea of their method of exploitation, their geological conditions and the treatment of their output. Before leaving Houghton, I will ask you to go with me to the top of one of the Quincy shaft-houses and take a general view of the country as it appears from that point of vantage. There will be Lake Superior men in Mexico, Africa or Australia, to whom the description will convey some of the warmth of *auld lang syne*.

It was a fine, clear morning; the west wind had blown away the mists, and while I regarded the widespread scene, as from a mountain top, it seemed good to be there. Looking due south over the multiplicity of trestles and tracks leading from the shaft-house, Quincy hill slopes steeply to the narrow arm of Portage lake; on the near side, just showing, are the roofs of Hancock; and across the water the straight streets of Houghton radiate in perspective from the quiet woodlands.

Over the bridge that unites the twin towns of Houghton and Hancock, the trolley cars are passing; while underneath, over a lower track, a Duluth, South Shore & Atlantic train is backing. Houghton stretches out thin along the water front; behind the two or three blocks of houses the streets become country roads, winding through clearings that are diversified by dark patches of forest. Beyond these again the rolling plateau holds the village that surrounds the Isle Royale mine with its two prominent shaft-houses, between which three rows of workmen's houses appear like orderly beehives; and in the distant background successive depths of forest fade into the faint blue of the Huron mountains.

Nearer to hand, and to the right, is the sheen of water

COPPER HARBOR.

marking a dam belonging to the Isle Royale mine, and swinging thence southwestward, along the line of the Quincy shaft-houses, the eye follows the general strike of the mineral belt as it is indicated by a succession of busy mines. About two miles south of the lake the red roofs of the Atlantic appear amid the green woods, and the smoke of that celebrated mine is thrown to the wind; behind it the country rises to Wheal Kate, a hill the name of which instantly brings Cornish associations. On the nearer side of this hill, but eastward, the smoke-stack and some of the buildings of the Baltic mine can be discerned, and on the wooded slopes below, two shaft-houses stand out against the trees. The nieghboring mines, the Champion and Trimountain, are only suggested by wreaths of smoke, for they are buried amid the bush that bounds the horizon.

Coming back to the foreground, but moving westward again, a grove of maples hides the valley of the Lake Arm, and almost eclipses the new Michigan smelter, whose thin smoke rises wind-blown on the further side. The country south and west, in this part of the picture, is checkered with cultivated squares, marking the industry of the Finns, whose farmhouses are many of them still unpainted and bespeak the newness of the agricultural development of this part of Michigan. Behind these fields of grain comes a fringe of woodland, indicating the descent to the main waters of Lake Superior, the southern edge of which is blurred by separate wreaths of smoke rising from the stamp-mills at Freda, where the Champion, Trimountain, Baltic, Adventure and Atlantic companies treat their ore.

The Portage Arm can be followed by the dip in the contour of the land, although the water itself cannot be seen; and, as the indent in the land is followed, it takes the eye westward to the alpine azure of the great lake—Lake Superior—whose far horizon is faintly broken by the mass of Isle Royale, sixty miles away, crowned by splendid cumuli which dissolve themselves in sunlit skies.

Following the Lake from west to north until the land rises against the watery horizon, there come into the foreground the streets of the village of Quincy, with the chimneys, dumps and rock-houses of the old Pewabic, Franklin and Mesnard mines. Northeastward there intervenes a ten-mile stretch of bush known to contain several mines none of which are visible except the Franklin, Jr. On the sky-line a cluster of chimneys indicates the great Calumet & Hecla; to the right is the Osceola, and to the left the tall stacks of the Red Jacket and the Tamarack, the deepest metal mines in the world, starting 600 ft. above the lake, itself 600 ft. above the sea, and penetrating nearly 4,000 ft. below the sea. Behind the bristling points of this group of black chimneys, the far end of the Keweenaw peninsula can almost be seen. Dark hills, far to the north, indicate the Cliff, where mining began in this region, and to the east of them the conical shape of Mt. Bohemia rises like a lone volcano.

Swinging eastward, the near view—and there is no other—is composed of a bare plateau broken by long rows of dwelling-houses, with the ill-fated Arcadian shaft-house silhouetted against the sky. Turning further to the right, and eastward, the entering wedge of Lake Superior again comes into the picture, and can be followed until it leads to Keweenaw bay. At our feet Quincy hill slopes to Portage Arm, and on the further shore the environs of Houghton end in a group of red-roofed buildings which mark the College of Mines. Here the Portage Arm widens into Portage lake, whose sinuous lines, leading to Keweenaw bay, are dotted with several steamers. On the shore of this bay is L'Anse, where dwell in tame subjection the Chippewas, the Indian tribe whose forefathers held sway over this goodly heritage of forest and stream. That smudge yonder by Keweenaw bay, is not a red hunter's camp fire, but rises from the tall stack of the Mass stamp-mill. Behind it is the level ridge of the Huron mountains, stretching north-

ward until they cleave Lake Superior with rocky promontory.

Nearer to us the smoke of the smelter at Dollar Bay, and that rising from the mills at Torch Lake, are thrown against a background of the flat woodland, rimmed by the blue waters of the great lake. These stretch eastward to a skyline broken by a wreath of smoke that follows in the wake of an unseen vessel, which carries with it all the wide suggestions of maritime commerce and swift communication with that great world of activity which is beyond our view. And so we pass from the copper mines of Lake Superior to other scenes.

A GLIMPSE OF LAKE SUPERIOR.